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RECONSTRUCTIVE SURGERY
Anatomy, Technique, and Clinical Applications

MICHAEL R. ZENN, MD, FACS
Vice Chief, Division of Plastic and Reconstructive Surgery,
Duke University Medical Center,
Durham, North Carolina

GLYN JONES, MD, FACS
Professor of Surgery, Department of Surgery,
University of Illinois College of Medicine,
Peoria, Illinois

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To my mother, Renee Schwam,
who has inspired me to dream big, then work hard to achieve.
She came to this country at the end of World War II,
not speaking the language, in search of a new life without persecution.
Despite the barriers that confronted her, she made a life for herself in America.
Throughout my life, whenever challenges faced the family
and things seemed bleak, she was the Rock of Gibraltar
and made certain her children were her priority.
I know that without her guiding light and example,
I could not be the surgeon I am today.
For all of her sacrifice and delay of gratification,
I wish to dedicate this book to her.

Michael R. Zenn

To my wife, Hilarie, for her constant love and cheerful support,
and our treasured children, Christy, Vanessa, and Stephen,
who are the source of my greatest pride
and by far my best contribution in life.

Glyn Jones
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Matthew Endara, MD
Resident in Plastic and Reconstructive Surgery,
Georgetown University Hospital,
Washington, DC

Detlev Erdmann, MD, PhD, MHSc
Associate Professor, Division of Plastic, Reconstructive, Maxillofacial, and Oral Surgery,
Department of Surgery, Duke University Medical Center, Durham, North Carolina

Karen Kim Evans, MD, FACS
Assistant Professor, Department of Plastic Surgery, Georgetown University Medical Center,
Washington, DC

Jeffery D. Friedman, MD
Chief, Plastic Surgery, Department of Surgery,
The Methodist Hospital, Houston, Texas;
Associate Professor of Surgery, Department of Plastic and Reconstructive Surgery, Weill Cornell Medical College, New York, New York

Guenter Germann, MD, PhD, FACS
Professor of Plastic Surgery-Hand Surgery,
University of Heidelberg, Ethanum Clinic for Plastic and Reconstructive Surgery, Aesthetic and Preventive Medicine at Heidelberg University Hospital, Heidelberg, Germany

Lawrence J. Gottlieb, MD, FACS
Professor of Surgery, Director of Burn and Complex Wound Center, Department of Surgery, Section of Plastic and Reconstructive Surgery, University of Chicago, Chicago, Illinois

Adriaan O. Grobbelaar, MBChB, MMed(Plast), FRC(Plast), FRCS(Plast), FRCS(ad eundem)
Department of Plastic and Reconstructive Surgery, Royal Free Hospital; Honorary Senior Lecturer, Division of Surgery, University College London, London, United Kingdom

Amit Gupta, MD, FRCS
Associate Clinical Professor, Department of Orthopedic Surgery, University of Louisville; Louisville Arm and Hand, Louisville, Kentucky

Geoffrey C. Gurtner, MD, FACS
Professor of Surgery, Professor of Materials Science and Engineering, Division of Plastic and Reconstructive Surgery, Department of Surgery, Stanford University School of Medicine, Stanford, California

Geoffrey G. Hallock, MD, FACS
Consultant, Division of Plastic Surgery, Sacred Heart Hospital, Allentown, Pennsylvania;
Consultant, Division of Plastic Surgery, St. Luke’s Hospital, Bethlehem, Pennsylvania

Moustapha Hamdi, MD, PhD
Professor and Chairman, Department of Plastic and Reconstructive Surgery, Brussels University Hospital; Professor, Department of Plastic Surgery, Edith Cavell Medical Institute, Brussels, Belgium

Matthew M. Hanasono, MD, FACS
Associate Professor, Department of Plastic Surgery, The University of Texas M. D. Anderson Cancer Center, Houston, Texas

James P. Higgins, MD, FACS
Chief, The Curtis National Hand Center, Union Memorial Hospital, Baltimore, Maryland

Jung-Ju Huang, MD
Assistant Professor, Division of Reconstructive Microsurgery, Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, Taoyuan, Taiwan

Marco Innocenti, MD
Director, Reconstructive Microsurgery Division, Department of Oncology, Careggi University Hospital, Florence, Italy

Ian T. Jackson, MD, DSc (Hon), FRCS, FRACS (Hon)
Professor Emeritus, Beaumont Health Systems, Royal Oak, Michigan

Leila Jazayeri, MD
Resident in Plastic and Reconstructive Surgery, Division of Plastic and Reconstructive Surgery, Department of Surgery, Stanford University School of Medicine, Stanford, California
Glyn Jones, MD, FACS  
Professor of Surgery, Department of Surgery,  
University of Illinois College of Medicine,  
Peoria, Illinois

Sebat Karamürsel, MD  
Associate Professor, Department of Plastic and Reconstructive Surgery, Ankara Diskapi Hastanesi, Ankara, Turkey

Joshua L. Levine, MD  
Chief of Surgical Services, Department of Plastic and Reconstructive Surgery, New York Eye and Ear Infirmary, New York, New York

Samir Mardini, MD  
Professor of Surgery, Department of Surgery,  
Mayo Clinic College of Medicine,  
Rochester, Minnesota

Frederick J. Menick, MD  
Chief, Division of Plastic Surgery,  
St. Joseph’s Hospital, Tucson, Arizona

Steven L. Moran, MD  
Professor and Chairman of Plastic Surgery,  
Professor of Orthopedic Surgery, Division of Plastic Surgery, Division of Hand Surgery,  
Mayo Clinic, Rochester, Minnesota

Steven F. Morris, MD  
Professor of Surgery, Professor of Anatomy and Neurobiology, Department of Surgery, Department of Anatomy and Neurobiology, Dalhousie University, Halifax, Nova Scotia, Canada

Edwin J. Morrison, MBBS, LLB, BComm(Eco)  
Resident, Department of Plastic Surgery,  
St. Vincent’s Hospital, Melbourne, Victoria, Australia

Wayne A. Morrison, AM, MD, BS, FRACS  
Fellowial Fellow, Department of Surgery,  
St. Vincent’s Hospital, University of Melbourne, Victoria, Australia; Director, O’Brien Institute, Melbourne, Australia

Peter C. Neligan, MB, FRCS(I), FRCSC, FACS  
Professor of Surgery, Director, Center for Reconstructive Surgery, University of Washington Medical Center, Seattle, Washington

Michael W. Neumeister, MD, FRCSC, FACS  
Professor and Chairman, Division of Plastic Surgery, Southern Illinois University School of Medicine, Springfield, Illinois

Norbert Pallua, MD, PhD  
Professor, Chairman, Department of Plastic Surgery, Hand Surgery, Burn Center, RWTH Aachen University Hospital, Aachen, Germany

William C. Pederson, MD, FACS  
Adjunct Professor, Department of Surgery, Division of Plastic Surgery, The University of Texas Health Science Center at San Antonio; President and Fellowship Director, The Hand Center of San Antonio, San Antonio, Texas

Julian J. Pribaz, MD  
Professor of Surgery, Harvard Medical School, Brigham and Women’s Hospital, Boston, Massachusetts

Lee L.Q. Pu, MD, PhD, FACS  
Professor of Surgery, Department of Surgery (Plastic Surgery), University of California, Davis, Sacramento, California

Justin M. Sacks, MD, FACS  
Assistant Professor, Department of Plastic and Reconstructive Surgery, Johns Hopkins School of Medicine, Baltimore, Maryland

Michel Saint-Cyr, MD, FRCSC  
Associate Professor, Department of Plastic Surgery, University of Texas Southwestern Medical Center, Dallas, Texas

Luis R. Scheker, MD  
Associate Professor of Plastic Surgery, Department of Surgery, University of Louisville, Louisville, Kentucky; Associate Consulting Professor of Surgery, Department of Surgery, Duke University, Durham, North Carolina
Experts Providing Commentary and Clinical Cases

Minoru Shibata, MD, PhD
Professor and Chief, Department of Plastic and Reconstructive Surgery, Niigata University, Graduate School of Medicine and Dental Sciences, Niigata Prefecture, Japan

Roger L. Simpson, MD, MBA, FACS
Assistant Professor of Surgery, State University of New York Stony Brook, Stony Brook, New York; Long Island Plastic Surgical Group, Garden City, New York

Aldona J. Spiegel, MD
Director, Center for Breast Restoration, Assistant Professor, Weill Cornell Medical College, Institute for Reconstructive Surgery, The Methodist Hospital, Houston, Texas

Milan Stevanovic, MD, PhD
Professor of Orthopaedics and Surgery, Department of Orthopaedic Surgery, Keck School of Medicine of University of Southern California, Los Angeles, California

Robert L. Walton, MD, FACS
Professor of Surgery, Department of Surgery, Division of Plastic Surgery, Northwestern University Feinberg School of Medicine, Chicago, Illinois

Fu-Chan Wei, MD, FACS
Professor, Department of Plastic Surgery, Chang Gung Memorial Hospital, Chang Gung Medical College and University, Taipei, Taiwan

Timm P. Wolter, MD, PhD
Attending, Department of Plastic Surgery, Hand Surgery, Burn Center, RWTH Aachen University, Aachen, Germany

Peirong Yu, MD, MS, FACS
Professor, Department of Plastic Surgery, The University of Texas M. D. Anderson Cancer Center, Houston, Texas

Michael R. Zenn, MD, FACS
Vice Chief, Division of Plastic and Reconstructive Surgery, Duke University Medical Center, Durham, North Carolina

Ronald M. Zuker, MD, FRCSC, FACS, FRCS(Ed)(Hon)
Professor of Surgery, Department of Surgery, University of Toronto; Attending Plastic Surgeon, The Hospital for Sick Children, Toronto, Canada
Foreword

This book fulfills a promise that Steve Mathes and I made in February 1987 when we planned the first edition of *Reconstructive Surgery: Principles, Anatomy, & Technique* with Karen Berger at QMP. At that time we contracted to produce a third work that would build upon the flap anatomy in the initial two-volume book while adding new techniques and specific clinical applications for each flap. In the intervening years, the project stalled when Steve became ill and I became more involved with aesthetic surgery. Now, however, I am delighted and honored to be able to write a foreword for this new book: *Reconstructive Surgery: Anatomy, Technique, and Clinical Applications*, written by two master surgeons, Michael Zenn and Glyn Jones, who have taken up the mantle and completed what we began so many years ago.

Drs. Zenn and Jones have produced a landmark work that fulfills the legacy of the first book. It captures the detailed flap anatomy, design and markings, and basic technique of the initial work while adding valuable new information on flap dissection technique, flap variants and options such as perforator flaps, clinical applications, pearls and pitfalls, and expert commentary.

This long-anticipated book does not disappoint. The artwork is rendered in a simple yet elegant style that clearly depicts key structures and techniques. Helpful icons and opening outlines enhance the learning experience, as do the summary boxes, which focus on pearls and pitfalls for each flap. The expert commentary at the conclusion of each chapter is a terrific addition; it provides valuable perspective on these flaps by leading experts in the field.

This superb text provides today’s reconstructive surgeons with the tools to solve complex reconstructive problems with new surgical options. It is destined to become the standard for young and experienced surgeons alike as they seek optimal solutions for difficult reconstructive problems. We owe a debt of gratitude to the authors and to the publisher for making this book a reality after so many years and for providing our specialty with a classic textbook to guide us.

**Foad Nahai, MD, FACS**
Paces Plastic Surgery
Atlanta, Georgia
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Foreword

In 1961, President Kennedy’s inaugural speech referred to “the torch being passed” to a new generation. The torch of plastic surgery has been reconstructive techniques that treat myriad afflictions of the human condition: congenital deformities, traumatic injuries, oncologic conditions, and infections. Our toolbox has expanded exponentially in the past half-century.

Sixteen years ago, the first edition of *Reconstructive Surgery* became the bible for reconstructive surgeons. The ability to move tissue on vascular pedicles and perform autogenous tissue transplantation using the operating microscope welcomed the modern era of reconstructive surgery. The first edition demonstrated the anatomy of flaps and the basic techniques and applications. Now the torch has been passed from masters of modern reconstructive surgery, Foad Nahai and Stephen Mathes, to two outstanding leaders in reconstructive surgery, Michael Zenn and Glyn Jones. Dr. Michael Zenn served with distinction as my partner at Duke, and I observed his passion for reconstructive surgery, education, and clinical excellence with pride and respect. Dr. Jones’s path to authorship of this book is a wonderful testimony to America and American medicine. A native of Zimbabwe, he emigrated to the United States and has made his mark in reconstructive plastic surgery and as an author/editor. For any educational event that I was fortunate to organize relating to reconstructive surgery, Glyn was always on the top of my list as a faculty member. Both authors have a keen sense of organization, clear expression of thought, and attention to detail to create excellence in everything they do. This book is a written testimony to these attributes.

It is essential that the reconstructive plastic surgery community have a definitive reference delineating anatomy, applications, and the limitations of these techniques. This new landmark publication fulfills that need; it is superbly organized, beautifully illustrated, and is authored by two reconstructive surgeons who are internationally recognized for their innovation and contributions to the field. There is such a wealth of information that this text will serve us well for the future, providing information that will allow further development of reconstructive surgery and new applications using the time-honored anatomy that is our compass in surgery. It will be embraced not only by the new generation of students, residents, and fellows, but will also inspire the practicing plastic surgeon to establish the foundation of a procedure correctly each day in the operating room by laying down the principles of reconstructive surgery.

L. Scott Levin, MD, FACS
Paul D. Magnuson Professor of Bone and Joint Surgery
Chair, Department of Orthopaedic Surgery
Penn Orthopaedics
Hospital of the University of Pennsylvania
Philadelphia, Pennsylvania
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Progress is never achieved in isolation. To advance any field, we need to acknowledge those who have come before us and recognize how their contributions have enhanced our understanding. We must then stand on the shoulders of those giants who have preceded us and move the specialty forward. In the area of reconstructive flap surgery, there are no broader shoulders than those of Stephen Mathes and Foad Nahai. The original Mathes-Nahai text on muscle flaps was epic, ushering in a new era of reconstructive surgery. For many of us students of plastic surgery, this was the first text that we purchased in the field, guiding us on our path to becoming competent plastic surgeons. It was a detailed guide to safe flap dissection as well as an inspiration to generations of plastic surgeons.

Years ago, Glyn Jones’s former partner at Emory, Foad Nahai, and colleague Steve Mathes invited Glyn to contribute to a new clinical applications book that they were planning; it was intended as a comprehensive replacement for their landmark flap book. Unfortunately, this project was shelved when Steve became ill, but the idea persisted. As time passed, it became increasingly obvious that, while the earlier book was still an invaluable resource, it was in serious need of an update, both in the scope of flaps covered and in the style that has become the standard for our times. The new text you are holding fulfills that need and the dream of the original authors.

In preparing this book, we are very much aware of how quickly plastic surgery is changing, particularly in the area of flap surgery. Advances in microsurgical techniques and applications, combined with the explosive growth of perforator surgery, make any attempt at writing a “complete” text on flap surgery daunting. These volumes are intended to be as inclusive as possible, given our current knowledge of the field and our best guess as to which flaps will prove most valuable in the future.

We have planned this text to be a helpful companion for the reconstructive surgeon, both in flap selection and in flap execution. To accomplish that goal, it is organized into two major Parts: Fundamentals and Regional Flaps (Anatomy and Techniques). Part I is introduced by a Reader’s Roadmap that explains how the book’s chapters and flap descriptions have been organized and helps the reader navigate its pages. Following this introduction are four key chapters. The first focuses on decision-making and surgical principles while the second by Drs. Steven Morris and Peter Davison presents invaluable information on the vascular basis and classification of flaps. Further guidance is provided in Chapter 3 with its regional treatment of flaps. This chapter outlines the possible flap options in each area of the body and serves as a useful starting place for finding the ideal flap for a particular problem. The final chapter in this section discusses complications, why they occur and what we can do to avoid them.

Part II is divided into separate chapters for each anatomic region. Within those chapters, the basic anatomy of each of the commonly used flaps is carefully outlined in a consistent format to make this text a quick and easy reference for locating critical information. Throughout, we have provided many useful dissections, pairing photographs and radiographs with detailed medical illustrations to depict dissection technique and other technical points emphasized in the text. Clinical cases demonstrate applications for each of these procedures, showing their versatility wherever possible. We are particularly grateful to the experts who have joined us in this endeavor for their sage comments and the cases they have contributed.
This enormous reservoir of pooled information and expertise will benefit us all as plastic surgeons and make a useful and timely contribution to our exciting field.

Our collaboration has been a delightful experience as we each have had a wide experience of reconstructive and aesthetic plastic surgery and we both enjoy microsurgical reconstruction. A long-standing friendship and deep personal respect for one another has fueled a collaborative effort that has made this project a particularly rewarding endeavor. Working together for several years as instructors at the renowned Duke Flap Workshop and seeing the innovative advances demonstrated by an international faculty of experts have provided further fuel for the text. It has allowed us to refine concepts and provide the most up-to-date advances and modifications to many of these flaps that have been reported by our colleagues throughout the world.

As this project comes to fruition, we sincerely hope that it will enrich the lives of our patients. We also hope that generations of plastic surgeons to come will benefit from the wealth of collective knowledge outlined in these two volumes. We are both humbled and grateful to have been given this extraordinary opportunity.

Michael R. Zenn
Glyn Jones
It was quite by accident that I was introduced to plastic surgery. I was a rotating fourth-year medical student from Cornell who signed up for a month of general surgery subinternship at the Massachusetts General Hospital with my friend, Andy Kenler. His brother-in-law, an MGH resident, got him on the premiere surgical oncology service while I got stuck on the thyroid service. After a week of seemingly endless thyroidectomies I was bored, and got my friend Andy to appeal to his brother-in-law to get me on another service. That brother-in-law was Louis Bucky, now on faculty in plastic surgery at the University of Pennsylvania; then, he was a senior general surgery resident rotating on the plastic surgery service. He got me on the service for my remaining time, and my life path was forever changed. The hustle and bustle of the plastic surgery service, the variety and complexity of the surgeries, and the iconic James W. May, Jr., were all it took to plant the seed that would take root after my training in general surgery.

Ironically, some 5 years later, I would end up at Massachusetts General again, this time as a plastic surgery resident. The intensity of that training could not be replicated today (without violating multiple ACGME rules), but the experience became the crucible that molded me into the plastic surgeon I am today. My mentors at MGH included one of the greatest teachers I have ever met and emulate daily—James W. May, Jr. I was also fortunate to train side by side with Gregory Gallico, Michael Yaremchuk, Michael Lewis, Peggy Howrigan, Matthew Donnelan, and W.P. Andrew Lee, just a first-year attending at the time. The training was intense and grounded in traditions dating back to Bradford Cannon, one of the founders of our specialty and a regular at our weekly conferences. I was heavily influenced at the time by my co-residents, who included Lou Bucky (then my chief resident), Craig Johnson (our hand fellow), Jeffrey Ditesheim, Neal Chen, Matt Concanon, and Fred Duffy.

Some early experiences at Memorial Sloan-Kettering Cancer Center while a Cornell general surgery resident introduced me to the world of microsurgery, so it only seemed appropriate that I study under the master himself, David Hidalgo, as a MSKCC microsurgery fellow. While working with David, I saw first hand the amazing power that microsurgery had to solve difficult problems and to transform lives. Most of all, it was his artistry and attention to the smallest details that stuck with me and torture my current residents on a daily basis. I was fortunate at that time to also work with Peter Cordeiro, now the chief at MSKCC, who has remained a good friend.

Early in my practice, I was fortunate to meet the man who would have the greatest influence on my career, L. Scott Levin. As Chief of Plastic Surgery, Scott welcomed me to Duke with open arms. I was not a competing microsurgeon, but a partner in what would be an incredible 10-year voyage of discovery, growth, friendship, and the creation of something special in the Duke Flap Course.

I have always known I would be an educator. Second only to operating and caring for patients, teaching residents and fellows the art and science of plastic surgery has been my life’s work. It is true that the bond between teacher and student is a special one, and I would be remiss if I did not also give thanks and acknowledgment to the residents and fellows I have had the honor to train. We in academics are fortunate to be exposed to bright, energetic minds on a daily basis. One source of annoyance when training residents is their constant
questioning of the status quo. However, I must admit that it has been this pressure that has allowed my practice to evolve continually and stay at the cutting edge of plastic surgery.

It has been an incredible honor to co-author this text with Glyn Jones. As a young surgeon, I always looked up to Glyn as someone in academic surgery to emulate. He is a bright, talented surgeon who, like me, has always had a passion for teaching and enriching the lives of patients. Our long weekends at QMP in the “dungeon” will be fondly remembered. Our shared passion in creating this text has cemented a friendship for life.

I would also like to thank and congratulate the invited experts who wrote commentaries and provided additional clinical cases for a job well done. Our specialty is full of incredibly talented people, and this has been ably demonstrated through their insights.

We learn early in our surgical careers that success comes with a price. The time required to care for patients and even write this book has to come from somewhere and all too often it is our own family who suffers. I have been fortunate to have an incredible family who support my endeavors and have never complained when I have been called away or missed an event. My wife and soulmate, Susan, my son, Andrew, and my daughter, Erica, are a continual source of joy and encouragement. My other “family,” my nurse of 15 years, Jo Ann Garofalo, also deserves my special thanks for helping me to hone my craft and care for our patients, many of whom are demonstrated in this book.

Last, but certainly not least, I want to thank Karen Berger at Quality Medical Publishing, without whom this text would not exist. Her decades of experience in medical publishing have given her a true understanding of the needs of the plastic surgeon and the plastic surgery educational market. Once she decides to take on a project, she has the uncanny ability to take an author’s vision and make it a reality, often surpassing expectation. To know her is to love her, but make sure you meet your deadlines! The family that Karen has built at QMP is a special one and includes Amy Debrecht, Michelle Berger, Taira Keele, Andrew Berger, Suzanne Wakefield, Carolyn Reich, Brett Stone, Ngoc-Thuy Khuu, Carol Hollett, Rebecca Sweeney, and Lane Wyrick. The artistry of Brenda Bunch, Amanda Behr, Amanda Tomasikiewicz, Eric Olson, Jennifer Darcy, and Jennifer Gentry has raised the bar for medical illustration in a reconstructive text. My sincere thanks to all at QMP for your hard work and the passion you displayed creating this text. It is my hope that over the years, plastic surgeons will continue to thank you for this job well done.

Michael R. Zenn
Acknowledgments

Just over 34 years ago I completed my internship and was called up to a year of National Service during the bloody and tragic civil war in my former homeland of Rhodesia, now Zimbabwe. Committed as I was to a career in surgery, I spent a year dealing with combat casualties as well as the usual run of civilian surgical pathology. It was during that life-changing year that I was drawn repeatedly to the finesse of facial and hand reconstruction and the dilemma of closing large defects inflicted by warfare. Those early experiences were to become the stepping stones that would lead to a career in plastic surgery. Although general surgery enthralled me, a rotation through plastic surgery at the University of Cape Town convinced me that it was here where my future lay. After completing my general surgery residency in Cape Town, I was fortunate to be accepted to the plastic surgery program in Cape Town. While training there, Guy Trengrove Jones and Roger Strover inspired me to seek further fellowship training in the United States, and in 1988–1989 I spent 2 years undergoing postgraduate plastic surgical training at Norfolk, Virginia, Atlanta, Georgia, and then St. Louis, Missouri.

My time at Emory University in Atlanta was probably the most life-changing experience of my entire career. It was here that I came under the tutelage of Josh Jurkeiwicz, a born teacher and inspiration to several generations of surgeons. Josh was a man who regarded the transmission of knowledge to his residents as his life’s work and a God-given responsibility, not only for the benefit of the surgeons on his watch, but for the patients those surgeons would ultimately treat. He had attracted a dynamic faculty and trained more future chairmen of plastic surgery than any other plastic surgeon in this country’s history. It was as a fellow at Emory that I was exposed to the dynamism of Foad Nahai, John Bostwick, Rod Hester, and their fellow trainees John McCraw, P.G. Arnold, Steve Mathes, Luis Vasconez, and Leonard Furlow. You cannot be in the presence of these men without having your life seared by the flame of their contagious enthusiasm. They changed my entire perspective on plastic surgery, retooling the way I approached problems, and kindled within me an undying love for breast surgery and complex reconstruction that remains with me today. My relationship with John Bostwick became a lifelong friendship curtailed by his untimely death, but it allowed me the privilege of rewriting his famous text on breast surgery for future generations, a privilege I will always cherish.

While still a fellow at Emory, I spent a weekend in St. Louis with Foad Nahai and Steve Mathes, meeting Karen Berger for the first time as we discussed contributing to a clinical companion text to the original Mathes–Nahai reconstructive books. The “flap book” was a must-have text for any plastic surgeon embarking on reconstructive procedures, and despite its age, it has remained a landmark text that has helped countless surgeons better perform the reconstructions from which so many patients have benefited over the years. As time wore on and innovations emerged, however, it became clear that a companion text was needed—one that incorporated the information from the previous reconstructive work while adding important clinical applications and expert commentary. It has been a privilege to be involved in writing this monumental text. Foad Nahai has been tremendously supportive of our efforts, and I will always be grateful to him for his support, friendship, and encouragement over the years.
Karen Berger is a remarkable woman who has left an indelible mark on the plastic surgery publishing world. As Mike Zenn said in his acknowledgments, “to know her is to love her,” and having known and worked with her for over 20 years, I can wholeheartedly affirm that statement. Karen is an extraordinarily motivated publisher who drives us hard as a team but delivers far more than one could have hoped for. The quality of her work and the books she produces are unmatched in the world of plastic surgical publishing. No publisher can achieve what she has without the support of an outstanding team. Karen has put together an excellent team at QMP with whom it has been both a pleasure and privilege to work. Amy Debrecht, Michelle Berger, Taira Keele, Suzanne Wakefield, Carolyn Reich, Brett Stone, Ngoc-Thuy Khuu, Carol Hollett, Rebecca Sweeney, Lane Wyrick, and Andrew Berger are a formidable publishing team who spend countless hours preparing the text for publication and marketing it to the world, and we are indebted to them for their meticulous efforts.

This book could not exist without the remarkable artistry of the medical illustrators who have infused its pages with beautiful imagery. The quality of the artwork reflects the skill of Brenda Bunch, Amanda Behr, Jennifer Gentry, Jennifer Darcy, Eric Olson, and Amanda Tomasikiewicz, whose combined efforts have created a visually stunning body of art to accompany the text. The QMP team is to be congratulated for a job well done.

In preparing something as monumental as this two-volume book, Michael Zenn and I have had to work together for hours as a team. It has been a privilege to know Michael as a colleague and a friend, and this book has been a catalyst in strengthening an enduring friendship and mutual respect. We both love to teach, and we hope that the pages of this book will help generations of plastic surgeons to come.

Works such as this do not come to fruition without considerable sacrifice. We are both busy clinical surgeons with mature practices, and time is always at a premium. In embarking upon such a project, we were acutely aware that the time commitment would be enormous. That time is garnered at night and on weekends, and it comes at the expense of time with our wives and families. I want to pay tribute to my wife, Hilarie, for her enduring support and encouragement during this second tour de force in my writing career, for without it, the project would never have matured.

It is my hope and prayer that this book will be an invaluable tool in plastic surgical training, not only as a resource for surgeons, but above all, for the benefit of our patients, without whom the need for this book would never exist.

Glyn Jones
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   A. Abductor Digiti Minimi Flap 1734
   B. Flexor Digitorum Brevis Flap 1754
   C. Abductor Hallucis Flap 1772
   D. Dorsalis Pedis Flap 1788
   E. Medial Plantar Artery Flap 1812
   F. Lateral Calcaneal Flap 1834

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Part I

Fundamentals

Reader’s Roadmap
Surgical Decision-Making: Options, Principles, and Techniques
Vascular Basis and Flap Classification
Guide to Flap Selection
Complications: Avoidance and Treatment
Successful outcomes in reconstructive surgery depend on the interplay of a number of key factors. A comprehensive understanding of anatomy is of primary importance. Once mastered, this must be combined with surgical training, clinical judgment, and technical skill. Equally important, a surgeon must be able to effectively analyze the problem at hand, identify all potential options for its solution, and select the reconstructive approach that most effectively and aesthetically restores the lost form or function while minimizing donor site deformity. Compared with our predecessors, who could not have foreseen our current concept of angiosomes or the advent of perforator flaps, our choices are greater and the range of deformity treated is wider. With this knowledge also comes complexity and an increased level of technical difficulty that our teachers never had to contend with. That said, with our improved understanding of human anatomy, coupled with advances in flap design, we are able to steadily move forward, accomplishing more with better outcomes.

This book should be thought of as a roadmap for navigating the wide range of reconstructive problems we see throughout the body. It is a tool for selecting the best solutions for these problems. It has been formatted to be a quick, easy-to-read reference guide that surgeons can use when determining options for a particular problem, delineating the appropriate anatomy, and showing the step-by-step dissection technique for the chosen flap. Clinical examples further demonstrate what is possible with each flap, and insights from invited experts ensure that you know their tricks.

Building on the systematic approach established in earlier books authored by the iconic Mathes and Nahai, our book employs a similarly structured format. The text has been organized into two distinct sections: Part I: Fundamentals, and Part II: Regional Flaps: Anatomy and Basic Techniques.
The text begins with a section on fundamentals that includes four key chapters. The first chapter is “Surgical Decision-Making: Options, Principles, and Techniques.” It presents the essential building blocks for understanding and using the flap concepts and designs that follow. It also contains basic information on the subset of free tissue transfers and guidelines on flap monitoring.

The second chapter, contributed by Steven Morris, discusses the vascular basis of flaps and the justification for flap classification. As the complexity and number of flaps grow, it is important that we can communicate clearly what tissues are involved and how they are vascularized and innervated.

The third chapter in this section is entitled “Guide to Flap Selection.” This unique chapter will be the one you will turn to again and again as a logical starting point when assistance is needed with clinical problem-solving. Once you know where the problem is located, a series of tables and regional maps, organized by anatomic area, will guide you to all the potential reconstructive solutions. Page numbers are keyed into these charts to quickly direct you to the appropriate chapters and the specific flaps of interest. These charts also highlight the commonly used recipient vessels in that area, which may influence the specific flap choice. This section is also ideal for determining a fall-back plan for your case or a secondary choice in addressing a complication.

Chapter 4, “Complications and Treatment,” considers patient selection, surgical planning, intraoperative factors, and postoperative care.

Part II: Regional Flaps provides the detailed information on anatomy, basic technique, and clinical applications required for planning and successful execution of your reconstructive procedure. An overview of the pertinent anatomy is provided in a list format that is comprehensive yet easy to grasp. For simplicity and ease of use, this part is divided into 10 individual chapters: Head and Neck, Anterior Thorax, Posterior Trunk, Upper Extremity, Hand, Abdomen, Abdominal Viscera, Thigh, Leg, and Foot. For this atlas only the most commonly used flaps are identified in each body region. Individual sections are then dedicated to each flap, providing everything the surgeon needs to know about its execution and application. Each section in the chapter follows a distinct and consistent format, beginning with a list of clinical applications, and a succinct summary of anatomic features, as shown on p. 5.
ANATOMY

Landmarks  Specific anatomic guideposts that assist the surgeon to identify all important structures to define the local anatomy and design each flap.

Composition  Classification of anatomic components: (1) fascia, (2) fasciocutaneous, (3) muscle, (4) myocutaneous, (5) bone, and other specialized tissues.

Size  Flap dimensions to aid in flap selection and assess whether primary closure will be possible.

Origin/Insertion  Bony connections of all muscle flap origins and insertions.

Function  The intended purpose and role that these tissues play in situ. This is important in selecting a flap while ensuring that as much tissue as needed is taken. Even more important, this allows the surgeon to evaluate potential morbidity from alteration of the donor site, including functional loss (range of motion or strength) and aesthetic loss after flap elevation. Synergistic muscles that retain local motor function after flap elevation are identified.

Arterial Anatomy (Pattern of Circulation)

Dominant Pedicle  Source of arterial inflow to the flap and circulation to maintain tissue viability. As noted by Mathes and Nahai, different tissues have different sources of vascularization. Practically, the type of blood supply will dictate the way the flap can be used.

Regional Source  Major vessel located in the region of the flap that represents the source of circulation to dominant pedicle.

Length  Distance from point of entry of pedicle into flap and regional source of circulation. This information will help determine the adequacy of that flap choice based on distance to the defect or recipient site.

Diameter  Measurement of external lumen diameter to assist in planning for microvascular flap transplantation and vessel match at the recipient site.

Location  Anatomic site of the vascular pedicle relative to the flap and its landmarks.

Minor Pedicle  Smaller pedicles in relation to dominant vascular pedicle of flap that also help to vascularize the flap but may not reliably maintain tissue viability on its own. Also listed for minor pedicles are regional source, length, diameter, and location.

Venous Anatomy

The accompanying and auxiliary vessels that provide venous drainage for the flap.

Nerve Supply

Motor  Source and location of motor nerve to the muscle flaps. Important data especially for design of a functional muscle flap. Also important when muscle function is not required and the surgeon wishes to avoid undesirable muscle contractions or enhance muscle atrophy at the recipient site.

Sensory  Source and location of sensory nerves that have an anatomic relationship to the flap. These data will assist in design of cutaneous components of the flap with potential for sensory innervation. This information also helps to predict potential sensory deficits at the flap donor site.
The discussion proceeds to flap design and markings, patient positioning, and operative technique. The basic flap design is described, as well as known flap variants. The principal flap design is described first; description of the common variants follows. Wherever possible, we have included technical points invaluable to achieving success. The sections on flap transfer, flap inset, and donor site closure summarize the technical aspects necessary for safe completion of the reconstructive procedure after flap elevation.

All too often, operative descriptions fail to mention key procedural tips that make or break the success of a surgery. The Pearls and Pitfalls section has been written in bulleted form with this in mind, to provide the reader with as comprehensive a list as possible, thereby reducing the potential for failure. This is also an excellent way to reinforce important flap details when returning to the chapter. Augmenting this section, our expert commentators provide further insights into the successful execution of the procedures described. Their contributions and presentation of clinical cases bring the utility of the flaps into focus, demonstrating a broad range of possible applications for each flap or variant. Although case presentations have had to be limited by space constraints, they are intended to expose the reader to the many clinical applications available and are not intended to be comprehensive or exclusive.

The annotated bibliography includes a selection of the most relevant literature on each flap. Although the articles cited are not intended to be all-inclusive, every attempt has been made to briefly summarize publications that support the use of a flap or provide data relevant to its applications in reconstructive surgery.

Each section has been liberally illustrated with high-quality anatomic drawings and cadaveric photographs. The diagrams have been rendered in a combination of black and white line and color to clearly identify key anatomic elements important to flap design and execution. Extraneous detail has been downplayed for the sake of clarity. Color correction and artistic standardization has been maintained throughout.

We hope that this text will aid trainees as well as experienced surgeons in the selection and performance of a wide range of commonly used flaps. The format has been designed for ease of use, and its visual presentation will easily imprint critical flap details on the reader’s memory.
Chapter 1

Surgical Decision-Making: Options, Principles, and Techniques

Reconstructive surgery combines science, anatomic knowledge, and surgical artistry to accomplish the goals of preserving life and restoring form and function. As plastic surgeons, we are called upon to treat defects ranging from small to large that often have a significant impact on function and on the patient’s sense of self-esteem. Accordingly, reconstruction of these defects may require anything from simple direct suturing to complex composite free tissue transfers in multiple stages. The selection of the most appropriate reconstructive modality requires a careful assessment of the risks and benefits of each procedure in the light of the patient’s clinical status. Procedures should be tailored to the individual’s needs in providing a safe and expeditious recovery with minimal morbidity. In some instances, that may require a simple skin graft, such as for a fasciotomy wound in a leg. Other defects may be solved most easily with a free composite tissue transfer, the most extreme example being a face transplant for massive facial soft tissue loss. Although complex in execution and postoperative management, the procedure provides a one-stage restoration of facial structures unparalleled by any other techniques to date.

THE RECONSTRUCTIVE PARADIGM

Surgical decision-making in general surgery has been simplified to some extent by outcomes-based algorithms that lead to clear-cut approaches and procedures suitable for dealing with a wide range of problems. By contrast, surgical decision-making in plastic surgery is complicated by the vast array of procedures suitable for a given problem, each one offering advantages and disadvantages. While this text attempts to provide the reader with an atlas of flaps to assist with the execution of a given procedure, the choice of procedure can be bewildering, especially for the neophyte.
In the past, the reconstructive ladder became a much-publicized tool to aid surgeons in decision-making.

In recent years, the ladder has been dismissed by many as being simplistic and outdated. Although this may be partially true, the ladder simply attempted to provide surgeons with a progressive approach to wound management, beginning with simple solutions such as direct wound closure, progressing to grafts, adjacent flaps, and then distant or free flaps. There is nothing inherently wrong with this approach, other than to say that it is not necessary to progress in a stepwise fashion from a simple operation to a more complex one, only to end with a free flap because the previous option failed. In other words, free flaps are not a last resort. The reconstructive ladder never attempted to suggest that. It merely suggested a progressively more complex approach, using the simplest technique possible if it was feasible and best for the patient. The problem with maintaining the hierarchy of the reconstructive ladder is that although a skin graft is appropriate management for a granulating fasciotomy wound of the leg, it is clearly not a viable proposition for a composite hemimandibulectomy defect. Similarly, while a split-thickness skin graft could be placed over viable tissues across a joint flexion crease, flexion contracture would be a certainty, and the patient would be better served with a full-thickness graft or flap procedure.

When considering reconstructive options, it is imperative to bear in mind that safe wound closure should be based on the selection of the most appropriate technique, whether simple or complex, to achieve effective wound-healing, while taking into account local wound requirements and complexity.
In an attempt to clarify some of these issues, the reconstructive triangle was proposed.

![Reconstructive triangle diagram](image)

Rather than suggesting a stepwise progression from simple to complex, the triangle concept allowed for a free flow between pedicled flaps, tissue expansion and free tissue transfer. Although attractive in some respects, this model does not give the surgeon any guidance other than to suggest that any of the above options may be useful (which we already know), and it does not allow for the use of direct closure or grafts. Also, it overstated the role of tissue expansion in daily reconstructive surgery. As such, it fails to provide a clinically useful roadmap.

Rather than this simplistic procedural triangle, it may be preferable to conceive of a triangle housing several interdependent components leading to wound closure.

![Interdependent components concept diagram](image)
When assessing a wound for closure, the reconstructive surgeon needs to evaluate a multiplicity of factors to determine which procedure is most appropriate. These include the patient’s general health, the location and size of the defect, concomitant systemic risk factors such as tissue irradiation, and the availability of tissue donor sites.

**Systemic Factors**

A patient’s pathology may result from either congenital or acquired conditions. Acquired problems may arise from trauma, infection, radiation therapy, neoplasia, or vascular or autoimmune causes. Defects may be stable or unstable and may range from physically deforming to life threatening. The patient’s underlying health plays an important role in determining when and what, if anything, should be done. Although some procedures are simple and can be performed under local anesthesia on an outpatient basis, others require lengthy general anesthetics with postoperative intensive care. A seriously ill patient may not tolerate such a complex intervention. It should be remembered that organ failure or major medical morbidity takes precedence over defect reconstruction. In recent years the use of negative-pressure wound therapy (NPWT) has allowed temporary wound control while other more serious medical and surgical emergencies are dealt with. Once the patient’s condition is stable, definitive wound closure can be performed.

A second group of patients includes those with functional disability or severe deformity without concomitant life-threatening illness. Patients may be severely incapacitated by these problems and require complex reconstructions. A patient with a grossly disfiguring facial burn may be socially stigmatized and suffer severe psychological sequelae without life-threatening consequences. The problem may be salvageable with a face transplant or a series of more standard operations.

Patients with severe neurologic impairment or a limited lifespan as a result of organ failure are not good candidates for complex reconstructions, particularly when such procedures rely on normal physiologic function as part of a successful recovery.

Systemic factors that impact wound-healing and flap survival include smoking, obesity, immunocompromised states, steroid usage, and cardiopulmonary impairment. When flaps are planned in high-risk patients, one should consider maneuvers to increase blood supply and improve the safety of the procedure.
Organ System Derangements That Contraindicate Surgery and Require Treatment Before Management of Complex Defects

<table>
<thead>
<tr>
<th>Neurologic System</th>
<th>Gastrointestinal and Pancreaticobiliary Systems</th>
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<tbody>
<tr>
<td>Space-occupying lesion with impending herniation</td>
<td>Infarction</td>
</tr>
<tr>
<td>Acute infarction</td>
<td>Obstruction</td>
</tr>
<tr>
<td><strong>Cardiovascular System</strong></td>
<td><strong>High-output fistulas</strong></td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td><strong>Kidney</strong></td>
</tr>
<tr>
<td>Acute cardiac failure</td>
<td>Acute obstruction</td>
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<tr>
<td>Acute peripheral vascular insufficiency</td>
<td>Acute failure</td>
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<tr>
<td>Compartment syndrome</td>
<td><strong>Hematopoietic System</strong></td>
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<tr>
<td><strong>Respiratory System</strong></td>
<td><strong>Shock (acute blood loss)</strong></td>
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<tr>
<td>Upper airway obstruction</td>
<td><strong>Bleeding disorder</strong></td>
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<tr>
<td>Acute respiratory insufficiency</td>
<td><strong>Endocrine System</strong></td>
</tr>
<tr>
<td></td>
<td>Acute adrenal insufficiency</td>
</tr>
</tbody>
</table>

Local Factors
Patients may be in good general health but have local wound conditions that place them at high risk for failure. Wound contamination, infection, radiation therapy, poor vascularity, extensive scarring, or exposure of underlying tissues such as bone, joint, tendons, viscera, or body cavities require widely differing approaches to reconstruction.

Defect Analysis
Analysis includes an evaluation of:

- Size
- Location
- Wound characteristics
- Adjacent tissue
- Potential donor sites

The wound bed should include an assessment of all tissue components, including:

- Tissue quality
- Skin
- Subcutaneous tissue
- Mucosa
- Vasculature
- Nerve supply
- Cartilage
- Bone

Wound characteristics include assessment of:

- Vascularity to the region
- Infection
- Desiccation
- Tissue viability and presence of slough or eschar
- Quality of granulation (if any)
- Presence or absence of radiation injury
- Degree of fibrosis and scarring
- Presence or absence of malignancy
Timing of Closure
The timing of wound closure is critical to a successful outcome. Operating on an unstable patient with hypoperfusion may result in potential flap loss. Godina demonstrated that performing a free tissue transfer to a lower extremity compound fracture 5 to 21 days after injury tends to be associated with higher flap failure rates and increased infectious complications. For severe contamination or overt infection, the wound should be adequately debrided and reassessed carefully, allowing time for inflammation to resolve before a complex reconstructive procedure is undertaken. With the advent of multidisciplinary approaches to treatment, early closure of wounds has become increasingly frequent. If surgery has to be delayed because of patient instability or organ failure, NPWT has played a major role in maintaining a temporary safe and clean environment before definitive coverage. Tumor extirpation followed by immediate reconstruction in cancer treatment has allowed primary closure with functional reconstruction in complex situations, with improvement in patient outcomes and reduced morbidity.

A SYSTEMATIC APPROACH TO WOUND CLOSURE: SURGICAL OPTIONS

Split-Thickness Skin Grafts
Split-thickness skin grafts are invaluable in the management of superficial, granulating clean wounds overlying stable surfaces. They are simple, easily performed, and take rapidly on a vascularized bed by imbibition and inosculation. They tend to shrink, contracting the original wound size in both area and depth, and can produce quite good aesthetic outcomes. Their inherent tendency to contract makes them a poor choice for use across joints and for correcting contractures. Because of their thin nature, they tend not to maintain their characteristic color and texture. Their donor sites are painful and leave potentially large surface area scars. Wounds with irregular surfaces often benefit from NPWT as the bolster over the skin graft to improve graft-to-bed apposition.

Full-Thickness Skin Grafts
Full-thickness grafts, by contrast, are more aesthetically pleasing and are widely used to correct or limit contractures. They provide better texture on the face and hands but produce large, full-thickness donor site defects requiring direct donor site closure, a factor precluding the harvest of very large grafts. Given their thickness, they are slower to develop a blood supply, and take is correspondingly slower. To succeed, these grafts require a freshly prepared, well-vascularized bed. Graft-to-bed apposition has to be meticulously maintained with bolster dressings to achieve complete take. Color match and contour are often better than those achieved with split-thickness grafts.
Local Cutaneous Flaps
Flaps are full-thickness blocks of tissue perfused by regional source vessels with varying patterns of supply. The nature of flap blood supply is the topic of Chapter 2. Traditionally, flaps were considered random in terms of blood supply, until the axial nature of the groin flap was discovered. The random concept led to complex tubed pedicle transfers in multiple stages to bring a given piece of tissue to its final destination, distant to its origin.

Random Pattern Flaps
The term random flaps has historically been used to refer to skin flaps raised without a known, named blood supply leading to more tenuous flap survival rates. The term has also been applied to flaps with a known blood supply at their bases, but that have been designed to include more distant areas of skin with the hope that these will survive on random extensions of the known supply into the distal tissue. This led to a somewhat hit-and-miss approach to reconstructive surgery.
With the discovery of the groin flap’s axial blood flow, reconstructive surgery took a major leap forward in both predictability and creativity. *Axial pattern flaps* refers to the supply by a named, identifiable source vessel. Taylor’s pioneering studies of skin vasculature, built on the concepts of Michel Salmon, demonstrated that all skin is perfused from perforators arising from or between the underlying muscles and fascial septa. As such, although these flaps are perfused by an unnamed vessel, they are in fact perforator variants of one sort or another, arising from named vessels.

**Propeller Flaps**

It is not uncommon for a surgeon to raise a flap based on Doppler identification of a small, unnamed perforator derived from a known regional source artery, which provides axial blood supply to the overlying skin island. When the design is an ellipse and the flap is transposed based on that perforator, the term *propeller flap* has come in vogue. Propeller flaps are a type of perforator flap. They are called propeller flaps because the flaps rotate around the pedicle in the same way a propeller rotates around its hub. They can be designed freestyle, meaning that the surgeon can identify a perforator and design a propeller flap based on it to cover an adjacent defect. The term also describes the technique by which the flap is rotated into the defect. Propeller flaps can be used anywhere, but are probably used most often in the lower limb. It used to be taught that a free flap was required for defects of the lower limb. Now, however, many of these defects can be closed with a propeller flap, replacing the need for a free flap and making things much simpler for the surgeon and the patient.
Based on these observations, use of the word *random*, as applied to flap blood supply, is rapidly becoming obsolete. Although it is true that a flap may have a perforator in its base, so-called random flaps are usually designed with a length that may outrun the axial blood flow, thereby leaving the terminal part of the flap as a random extension. It is in this situation that length-to-breadth ratios come into play: the greater the length-to-breadth ratio, the greater the risk of necrosis. The ideal ratio is 1.5:1, with a maximum of 2:1. If an axial blood flow enters the base of the flap, ratios of 3:1 to as much as 6:1 have been described in fasciocutaneous flaps such as the supraclavicular flap. This is also related to Taylor’s angiosome concept of blood flow, in which an adjacent vascular territory may be captured fairly reliably but more distant angiosomes will be more prone to necrosis. These local flaps can be either transposition or rotation advancement flaps and while invaluable in many situations, their usefulness is limited by their arc of rotation. Examples of such procedures are Limberg flaps in facial skin cancer closures and gluteal rotation advancements for pressure sore closure.
**Axial Perforator–Based Cutaneous Flaps**

Cutaneous flaps with a known axial or perforator inflow often have a longer arc of rotation, and some have the option of being converted to free flaps. Typical examples include the groin, radial forearm, and supraclavicular flaps. These flaps are usually cutaneous, but some may be raised as adipofascial alternatives. The effectiveness of these flaps should not be underestimated. For example, the supraclavicular flap, an axial perforator–based flap, has often led its proponents to abandon their free flap options entirely for head and neck reconstruction in favor of this reliable and easy-to-use local pedicled flap.

**Muscle and Myocutaneous Flaps**

Muscle flaps are based on axial or segmental vascular supplies. This discovery in the clinical context led to the next major advance in plastic surgery after axial pattern flaps had evolved. The classification of the various blood flow patterns is described in Chapter 2. Those flaps with dominant axial inflows can be raised as pedicled or free flaps, such as the rectus abdominis or latissimus flaps, whereas those with segmental supplies, such as the sartorius, external oblique, or biceps femoris, are used only as transposition flaps. Muscle flaps are bulkier, have excellent blood flow, and can fill large defects. Many can be raised with an overlying skin paddle. Their vascularity makes them useful carriers of oxygen, growth factors, and antibiotics into the wound-healing milieu. Some are used as functional transfers, such as the latissimus dorsi, pectoralis minor, and gracilis flaps.
Prediction of Arc of Rotation
The extent that a muscle may be elevated from its anatomic location and its subsequent ability to reach adjacent defects without devascularization determines its arc of rotation. The dominant vascular pedicle’s entrance site into the muscle determines the point of rotation. (See Mathes and Nahai Classification, Chapter 2.)

Only muscle distal to the point of rotation is used as a transposition flap. For muscle types I, II, III, and V, the point of rotation is usually at one end or the proximal third of the muscle. For type IV, however, only the proximal or distal third of the muscle can be safely elevated because of the segmental vascular pattern; therefore type V muscle has a limited arc of rotation.

In type II muscle, the two dominant vascular pedicles are positioned at opposing ends of the muscle; thus the arc of rotation is smaller, because the whole muscle may not survive transposition on one vascular pedicle.

Type V muscle has two arcs of rotation; the total muscle can be safely elevated on the dominant vascular pedicle that enters adjacent to the muscle insertion in the shoulder girdle. Division of this dominant vascular pedicle permits safe transposition (a reverse arc of rotation) on the secondary segmental pedicles entering the muscle adjacent to the origin in the midline of the trunk.

**Fig. 1-9**  A, Flap anatomy. B, Arc of rotation with flap elevation to the point of entrance of the vascular pedicle to the flap. Applications of the flap are based on standard arcs of rotation. C, Extended arc of rotation based on flap elevation with dissection of the pedicle to its regional source. D, Extended arc of rotation based on flap elevation with pedicle dissection and release of proximal fascia and/or muscle origin or insertion.
**Fascial and Fasciocutaneous Flaps**
Before the discovery of the importance of fasciocutaneous blood supply, skin flaps had been raised in the subcutaneous plane at the suprafascial level. Cormack, Lamberty, and Ponten, among others, discovered the enhanced blood flow to flaps achieved by simply incorporating the underlying fascial layer which carried with it fascial blood flow. The resulting fasciocutaneous flaps became a new vascular basis for flap design with considerably improved flap reliability. Fascial vessels were identified as running on the surface of the fascia, perforating either from the underlying muscles or from within the fascial septa between muscle groups. This important discovery, coupled with the earlier understanding of muscle flap blood supply, formed the basis of modern flap design based on an understanding of tissue perfusion and altered the entire course of modern reconstructive plastic surgery. Fascial and fasciocutaneous flaps play a major role in reconstructive surgery today. Examples of such workhorse flaps include the pedicled radial forearm flap and temporoparietal fascia flap.

**Composite Flaps**
Complex defects often require multicomponent flaps to achieve closure. A full-thickness mandibular defect may require skin, bone and intraoral lining, all of which can be supplied with a fibular or iliac crest composite free flap. Although usually used as free flaps, composite flaps can be used as pedicled procedures, as in a fibular translocation into an ipsilateral tibial defect or a pedicled iliac crest bone graft to treat osteomyelitis of the symphysis pubis.
Free Flaps
Microsurgical reconstruction has become a mainstay of modern plastic surgery. Although pedicled flap reconstructions carried reconstructive surgery well into the 1970s, microsurgery represented the next major course change in the development of modern plastic surgery. It completely transformed our ability to reconstruct defects by bringing the most appropriate tissue components into the field rather than being limited by what local tissues had to offer. Where in the past, a pedicled pectoralis major flap with incorporated anterior rib could be used for mandibular reconstruction, it was now possible to bring a vascularized, osteotomized iliac crest or fibular graft complete with skin coverage into the mouth. The potential for complex three-dimensional reconstruction advanced exponentially as a consequence of the microsurgical revolution.

Perforator Flaps
The analysis of cutaneous perforator blood supply and the concept of chimeric flaps has fueled an explosion of interest in perforator-based cutaneous flaps, many of them suitable for microsurgical transplantation, as discussed by Drs. Morris and Davison in Chapter 2. Not only do these flaps contain a reliable blood supply, but they also spare the underlying musculature from being violated. The quintessential example is the deep inferior epigastric perforator (DIEP) flap in breast reconstruction.

Fig. 1-11  A, Three major variants of perforator flap blood supply. B, Skin island based on a myocutaneous perforator, with complete muscle sparing.
While perforator flaps have in some respects transformed the landscape of microsurgical options, many of the traditional free flaps, including muscle, myocutaneous, and various forms of composite bone flaps remain in play today. Microsurgery was once considered the option of last resort, whereas now it is often viewed as the first and best option for a complex reconstruction. Forty years ago, a thumb loss may have been reconstructed by wrapping a corticocancellous bone strut with a groin flap to achieve a static post for opposition; today that same reconstruction would be achieved with a free toe-to-thumb transfer, producing a more functional, sensate outcome. Under these circumstances, the reconstructive ladder has been sidestepped in favor of the more versatile reconstructive triangle suggested earlier.

**Fig. 1-12**  
A, Fasciocutaneous flap elevated on its vascular pedicle. B, Remote donor site debrided with exposure of appropriate adjacent recipient vessels. C, Inset of the revascularized skin island showing microvascular anastomosis to recipient vessels. D, Closeup view.
Tissue Expansion
Although tissue expansion is not a flap procedure per se, it would be inappropriate to ignore the role of tissue expansion in reconstruction. While the utility of tissue expansion has receded in recent years with the advance of microsurgical reconstruction, it still plays an important role in breast, scalp, and burn reconstruction. Tissue expansion has also been invaluable in the management of congenital nevi in pediatric surgery patients. The original concept devised by Radovan incorporates the insertion of an inflatable silicone balloon into the subcutaneous tissues adjacent to a given defect. The healthy skin is sequentially expanded and stretched until the desired surface area is attained, then the expander is removed and the stretched skin is advanced into the defect. Recruitment of adjacent skin coupled with a direct increase in epithelium and improved vascularity to the skin all contribute to expansion's success. More recently, the use of acellular dermal matrices (ADM) allows tissue expansion in areas that are thin and otherwise would have required muscle coverage over the expander. This approach has revolutionized breast reconstruction with the placement of ADM over tissue expanders in skin-sparing and nipple-sparing breast reconstruction. Distraction osteogenesis is a modern adaptation of tissue expansion, allowing lengthening of bone and expansion of the surrounding soft tissues.

![Diagram of Tissue Expansion](image)

**Fig. 1-13** A, Expander placement. The dashed line shows the planned flap. B, The flap is now expanded on top of the tissue expander and will be advanced into the defect. This creates redundancy at the base, excised as Burow's triangles. C, Flap advancement and closure.
PRINCIPLES OF CLOSURE

Simple Linear Wounds
Clean linear wounds, such as excisions for small skin cancers or benign lesions, are often best closed with direct linear suturing. Large-diameter wounds, such as for an open fasciotomy, can be sutured as delayed primary closures or be skin grafted. The use of wound approximation devices can reduce wound diameter by progressive, continuous wound-edge traction over days or weeks, obviating the need for more extensive procedures. NPWT devices are also immensely helpful in reducing wound surface area before closure.

Fresh Lacerations
Clean, freshly lacerated tissues are best treated with primary closure, assuming adequate tissue volume to achieve closure safely without tension.

Clean Granulating Wounds
Larger surface granulating wounds are usually closed with split-thickness skin grafts, depending on surface area involvement. Grafting should be deferred if wounds are draining excessively or are associated with heavy growths of bacteria, particularly staphylococci, pseudomonal strains, or beta-hemolytic streptococci, the latter tending to dissolve skin grafts within days of application.

Contaminated Traumatic Wounds
All contaminated wounds must be thoroughly debrided and lavaged to remove impacted dirt and debris. It is usual for the wound to be packed and the patient brought back for a second-look procedure 24 or 48 hours later to evaluate wound cleanliness and stability before a complex reconstruction is undertaken. All contaminated or devitalized tissue must be removed before definitive closure is contemplated.

Infected Wounds
Infected wounds should be drained of all pus, and all necrotic material should be debrided back to healthy bleeding. Antibiotic therapy is never a substitute for adequate surgical drainage and debridement. For example, the treatment of osteomyelitis includes resection of any necrotic bone back to healthy punctate bleeding. Wound closure should be delayed until a stable, clean wound bed has been achieved and surrounding inflammation has resolved.

Necrotic Wounds
Wound necrosis creates an ideal milieu for bacterial proliferation. Because necrotic tissue is avascular, antibiotics cannot penetrate the mass of dead tissue. Adequate debridement is essential to achieving a clean, stable wound before closure. When assessing wounds containing necrotic tissue, the regional blood flow should be assessed carefully; a revascularization procedure before reconstruction may make the difference between success and failure. The classic example is of a diabetic with chronic foot ulceration with a monophasic waveform of the distal circulation on Doppler evaluation. Revascularization with femorodistal bypass may convert such a patient’s Doppler readings to a biphasic or triphasic waveform that is more likely to be compatible with improved tissue perfusion and oxygenation and chances for a more successful reconstructive outcome.
RECONSTRUCTIVE GOALS

Once the defect has been assessed and surgical options reviewed, reconstructive goals should be established based on safety and restoration of form and function.

Safety

Safety in plastic surgery involves achieving the fine balance between effective wound coverage and maintenance of patient health. Flap selection forms the basis of an entire chapter in this text (Chapter 3). Focusing on flap safety, it is clear that a well-vascularized flap placed into the defect without tension and with good primary healing and complete flap survival are all keys to success. For example, the transfer of a poorly vascularized sural flap onto the sole of the foot under tension with resulting flap loss does not meet the goal of a healed wound and demonstrates poor planning and execution.

When performing pedicled flaps, the surgeon should carefully assess the arc of rotation before committing to the procedure. If a flap cannot easily reach its destination, an alternative or a free flap should be sought. If an unusually large skin island is necessary, a vascular delay can always be added to improve and enhance flap vascularity.

Similarly, safe free flap surgery is measured by an excellent microsurgical anastomosis and a resultant viable free flap that achieves a healed wound without flap loss. It is intuitive that a successful outcome requires not only good donor vessels, but also excellent recipient vasculature. Small, damaged vessels in a radiated, scarred bed are unlikely to deliver adequate inflow for success. Current microsurgical success rates for elective free flaps should be in the 96% to 98% range, given current equipment and training standards. These percentages decline in surgical repair of traumatic injuries.

Form

When breast reconstruction first began with the advent of first-generation silicone implants, success was measured by the creation of a breast mound on the chest wall. The resultant structure was often a poor facsimile of the natural breast. Fifty years later, breast reconstruction has evolved into a discipline that allows near-perfect restoration of form, sometimes exceeding the appearance of the preoperative breast shape and size.
This evolution of technique epitomizes the concept of restoration of form and should be applied to all forms of reconstructive plastic surgery, whether one is dealing with a face, a breast, or an extremity. Closure of a wound by a bulky muscle flap is a worthy goal, but not an ideal one. An approach that allows an aesthetically pleasing outcome in addition to achieving the goal of closure is far more laudable. With the expanding array of perforator-based skin flap options, we are also in a better position to choose thin skin flaps that are more tailored to the defect, rather than being forced to rely on a few bulky options, as we were in the past.

Another concept that has come to our aid has been that of prelamination. This involves staging the creation of the flap at the donor site by delay incisions, lining the flap with grafts such as skin or mucosa, adding cartilage constructs, and even preplacing osteointegrated implants. This ensures viability and structural soundness before transfer, speeding the healing process at the recipient site and increasing the chances of ultimate success. When an entirely new flap is created by a first-stage placement of a vascular pedicle under the area of desired skin, the term prefabrication is used. Such flaps may also be prelaminated.

### Chimeric Flaps

The use of chimeric flaps has also expanded our arsenal of potential resources in reconstruction of difficult wounds. The term chimera refers to a beast in Greek mythology that was a composite of a lion, a goat, and a serpent. In similar fashion, the chimeric approach can provide a multiplicity of tissues on one vascular pedicle. A classic example of this is the anterolateral thigh (ALT) flap, whose vascular axis, the lateral circumflex femoral artery, can supply multiple muscles, fascial tissue, multiple cutaneous skin paddles, and vascularized bone all on one vascular pedicle for reconstruction of complex maxillary and mandibular defects.

![Chimeric Flaps](image)

**Fig. 1-15** Chimeric flap modification. **A**, Common vascular connections between subscapular artery and vein to dominant pedicle to latissimus dorsi, serratus anterior, and scapular flaps. *a*, Axillary artery and vein; *b*, crossing branch for serratus muscle; *c*, circumflex scapular artery and vein; *s*, subscapular artery and vein; *t*, thoracodorsal artery and vein. **B**, Common vascular connections between superficial circumflex iliac artery and groin flap, and superficial inferior epigastric artery and inferior abdominal flap. *ci*, Superficial circumflex iliac artery and vein; *e*, superficial inferior epigastric artery and vein; *f*, superficial femoral artery and vein.
When considering restoration of form, it is appropriate to consider donor site sacrifice as well. If providing a sound closure comes at the expense of unacceptable donor site morbidity, the procedure is hardly justifiable. Perforator flaps epitomize the concept of harvesting tissue with little or no donor site morbidity. Although the ultimate form at the flap recipient site is the primary basis of flap selection, deformity resulting from loss of form and/or function at the donor site should be minimized and acceptable to the patient.

Function

The ultimate goal of a successful procedure is a durable, stable, and functional result at the reconstructive site. Although a lesser procedure such as a skin graft may achieve closure, it may not be as durable or aesthetically pleasing as a more complex flap procedure.

While many defects require a simple closure, some require specialized functional restoration. These include:
- Skeletal support (bone and joints)
- Sensibility
- Animation (facial or hand)
- Hair growth (scalp and face)
- Conduit function (aerodigestive tract, bladder)

Both pedicled and free flaps can be used to meet these requirements, although microsurgery has certainly expanded our options. Bony restoration for skeletal stability is most critical in the face and extremities. We are fortunate to have available a plethora of bone and osteocutaneous flaps, some with additional muscle extensions for soft tissue bulk. These flaps are invaluable for the reconstruction of massive mandibular and maxillary defects. Traumatic hand injuries are always a source of bone and soft tissue loss, and creative options available for their restoration include functional joint transfers, toe transfers, and composite osteocutaneous flaps, some incorporating tendon (dorsalis pedis or radial forearm flaps).

Restoration of sensation is not normally included in reconstruction with a cutaneous skin island based on a muscle flap, such as the transverse rectus abdominus myocutaneous (TRAM) flap or latissimus dorsi myocutaneous flap. However, a cutaneous branch may be included in the flap design to allow anastomosis to a recipient cutaneous nerve for sensory input. In thumb reconstruction, a staged groin flap wrapped around a static bone peg will not provide sensation, whereas a single-stage free toe-to-thumb transfer will and is therefore preferable.
Regional sensation plays an important role in flap outcomes. A sensate individual with a wound over a pressure point is well served with a muscle or cutaneous flap, with little likelihood of recurrent breakdown, whereas a low lumbar paraplegic will be more prone to recurrent ischial ulceration with a nonsensate flap than a sensory flap (a vascular delayed neurosensory tensor fascia lata flap incorporating sensory components from T12 to L1).

Functional muscle transfer can be accomplished by pedicled muscle flaps or free innervated muscle transfers. Examples include transfers for facial reanimation or forearm flexion following Volkmann’s ischemic contracture. A pedicled latissimus dorsi or pectoralis major flap can help restore elbow flexion, and a temporalis turndown with a masseter transfer can help with facial reanimation. Similarly, free pectoralis minor or gracilis transfers to the face and gracilis transfers to the forearm can produce some outstanding results in carefully selected patients. When performing functional muscle harvest, careful attention should be paid to maintaining function at the donor site; adjacent muscles should be able to accommodate the muscle loss so as not to impair regional function.

Tissue expansion can be used strategically to bring additional hair-bearing skin into a defect on the scalp for alopecia, as well as providing wound closure. Today the art of hair transplant has advanced significantly enough to replace many of the hair-bearing flaps of the past.

Conduit function can be restored using preexisting natural conduits or by creation of conduits by tubing skin flaps. Jejunum and colon free flaps have been described for replacement of the cervical esophagus and for creation of a neovagina. Tubed free skin flaps using radial forearm, ALT, and regional pedicled pectoralis muscle have been described for the esophagus, while regional flaps such as TRAM, gracilis, gluteal thigh, and internal pudendal have been used for vaginal reconstruction.

**PRINCIPLES OF RECONSTRUCTION**

**Flap Design**
Flap design should take into account the size of the defect in relation to the tissue available from a given flap as well as the arc of rotation of the flap when pedicled flaps are used. Flaps should be designed slightly larger than the defects they are designed to close, given that tissues rarely stretch as much as anticipated. Where skin flaps are used, every effort should be made to make use of the lines of maximum extensibility (relaxed skin tension lines) to facilitate donor site closure. Skin flaps designed to fit a particular anatomic defect should be designed around a template of the defect. When using expanded skin flaps in delayed closures, the flaps should be raised first before re-creating the defect in case there is not enough flap available for closure, necessitating further expansion in the future.

**Flap Selection**
The details of flap selection are the basis of Chapter 3. However, some basic principles of flap selection are pertinent at this stage of discussion.

**TECHNICAL CONSIDERATIONS**
Precise anatomic knowledge is essential if many of these complex reconstructive procedures are to be accomplished successfully. External anatomic landmarks that can guide the surgeon should be identified beforehand.
Pedicle Identification and Elevation

Based on external landmarks, flap elevation is commenced and dominant pedicle identification should be performed and confirmed before any minor pedicles are divided. Doppler studies or preoperative multidetector CT (MDCT) scans or magnetic resonance angiography (MRA) can be very helpful in confirming the presence or absence of pedicles. Intraoperatively, indocyanine green fluorescence imaging is very helpful in locating perforators as well as delineating zones of perfusion. Once a pedicle has been identified, every effort should be made to preserve its integrity during flap elevation and to prevent twisting or kinking during flap transfer. The use of topical vasodilators (20% lidocaine or papaverine solution) can help to prevent or reverse the spasm induced by dissection of the pedicle. Hypotension, hypothermia, and the use of pressors should be avoided at all costs. When elevating perforator flaps such as the DIEP flap, attempts should be made to incorporate alternative venous outflow sources such as the superficial inferior epigastric vein (SIEV) to prevent venous congestion.

Flap Delay

There are times when a flap’s design will extend beyond its usual boundaries, and these extensions are needed for the reconstructive problem. One can improve the vascularity of such tissues by “delaying” the needed tissues, effectively training the tissues to live off the blood supply selected. This process requires time for vessels to dilate to increase the primary angiosome. Taylor demonstrated that each delay requires 3 to 7 days to achieve maximal effect, depending on the area of the body and its local vascularity.

Fig. 1-17  A, Designing a delayed flap is straightforward and relies on the concept that a flap with an equal base and height can survive anywhere on the body (such as $1 \times 1$, $2 \times 2$, $3 \times 3$). For example, for a normal flap design that is certain to survive, if one adds an extension to the design based on the width of the flap, this is effectively planning a $1 \times 1$ flap based on a random blood supply away from the flap, which would survive on its own. B, Next, the sides of the normal flap and the extensions are incised, leaving the base of the design and the end of the design intact. The area between the cuts is completely undermined, so the only blood supply to the undermined tissue comes from the base and end of the flap. C, After 7 to 10 days, the end of the flap is incised. If further length is required, further extensions are created every 7 to 10 days before division of the end of the flap. It is advisable to wait 7 to 10 days before moving the flap to maximize perfusion before twisting and turning the flap and potentially compromising flow. This scheme generally means a minimum of 2 weeks to perform the initial delay incisions (day 0), incise the end of the flap, completing the delay (day 7), and rotate the flap (day 14). This technique can fail if extensions are aggressively long, the tissues are not completely undermined, and the timing of the entire delay is compressed.
Tunneling Flaps for Transfer
Subcutaneous tunneling can allow a flap to reach its destination without severing the intervening skin bridge. Unfortunately, postoperative swelling within the tunnel or overlying skin bridge can result in pedicle compression, causing thrombosis and flap loss. If tunnels are being considered, they should be patulous and generous, never tight. Hemostasis should also be carefully checked within the tunnel to prevent development of a tunnel hematoma that could cause catastrophic flap loss.

Tension
Tension is another common cause of partial or complete flap loss. In pedicled flaps, tension bands running across the flap from the pivot point may cause necrosis of all tissue distal to the tension band. In free flaps, tension can result in either avulsion of the anastomosis or stretching of the pedicle, which predisposes to vascular thrombosis. Tension may also develop postoperatively from swelling, activity, or a hematoma or seroma that may develop under the flap. Drains effectively reduce seroma collections in the postoperative period.

Hemostasis
Ensuring meticulous hemostasis should be standard operating procedure for any surgeon. Hematomas cause flap or pedicle compression, with serious consequences for both the patient and surgeon. For dissecting extremity flaps, it is helpful to use a tourniquet for accurate visualization of neurovascular structures and to minimize blood loss. Tourniquets should be released at the end of the dissection, and hemostasis should be carefully achieved before flap transfer and to ensure that blood flow to the flap is adequate and reaches all components of the flap.

Blood Loss and Transfusion
Blood loss can be minimized with careful dissection technique and the use of cautery dissection. Excessive blood loss resulting in hypotension must be avoided. The question of transfusion in a patient with anemia has been the subject of debate in recent years, particularly in cancer patients, where even small-volume transfusions have been shown to slightly increase the risk of recurrence as a result of immune compromise induced by transfusion. In terms of postoperative hematocrit levels, slight hemodilution down to a hematocrit of 35% seems to reduce the likelihood of intravascular thrombosis, both within anastomoses and in the deep venous system. Patients should only receive a transfusion if they are symptomatic (syncope, dyspnea, hypotension). Low hemoglobin values will reduce oxygen delivery to the tissues.

POSTOPERATIVE MANAGEMENT
Positioning
Although every effort may have been made to prevent intraoperative compression within tunnels or around pedicles, incorrect postoperative positioning can induce similarly disastrous results. A head and neck free flap may be compressed because of neck flexion; the problem could be avoided by using a neck roll instead of a large pillow to provide cervical support. A Trach-Tie supporting a tracheostomy can occlude the pedicle of any flap traversing the neck. A free TRAM or DIEP flap anastomosed to the vessels within the axilla may be compressed if the patient’s arm is adducted completely or she is allowed to lie slightly onto the operative side. An abdominal reconstruction using a free flap anastomosed to the femoral vessels may kink when the patient sits in a chair. When performing flaps for decubitus ulceration in paraplegics, the use of air-fluidized beds dramatically unload the flap and buttocks to maintain perfusion above critical closing pressures of 32 mm Hg or more.
Dressings
Dressings tightly applied to an extremity can strangulate flaps or digit transplants by acting like a tourniquet. This is particularly true at the base of the flap or digit where the vessels enter the tissue. Plaster splints, tight bras, and aggressive binders can also compress tissues either within the flap or adjacent, causing postoperative complications. It would be a failure of postoperative care if a surgeon performed a flap to salvage a diabetic extremity, only to have the splint create a pressure point over the heel, leading to heel necrosis and ultimately amputation of the limb. Extremity flaps and replants should be elevated to reduce edema. Patients with flaps of the head and neck should be placed in an upright position to promote venous return and minimize swelling, since inadequate venous return and edema may compromise flap circulation.

Suction Drains
Closed suction drains are always used after flap surgery. Although they will not necessarily prevent hematomas, they reduce fluid accumulation and prevent seromas, which can increase pressure on the flap or pedicle and lead to infection. Drain management should be individualized to each patient situation. In general, drainage should be less than 20 to 30 ml per 24-hour period before drains are removed. Drains are usually contaminated within 24 hours of insertion, and if at all possible, they should not be left in immediate proximity to an implant. Fully fluted channel drains seem to be more effective and have less tendency to block than do perforated drains. Hubless channel drains are also much less painful for the patient when removed.

Perioperative Antibiotics
Administration of perioperative antibiotics is considered the standard of care for most major procedures. However, postoperative antibiotics have not been shown to be beneficial beyond the first 24 hours and may in fact increase complication rates. Antibiotics should only be given postoperatively if a wound is contaminated or frankly infected. In such circumstances, it is not usual to perform a flap; reconstruction should be delayed until sepsis has been controlled. There are no substantive data to show that the presence of drains warrants administration of long-term antibiotic cover.

Mobilization
Prolonged bed rest is rarely indicated after reconstruction, other than for paraplegics undergoing repair of a decubitus ulcer or patients having lower extremity or perineal reconstructions. Elevation and immobilization of upper and lower extremities for 7 to 10 days is invaluable to reduce edema and prevent high venous back-pressures clotting off venous anastomoses. In the lower extremities this is followed by non-weight-bearing for 6 weeks postoperatively. Range of motion exercises can be instituted by 7 to 10 days after surgery unless upper extremity tendon repairs have been performed in which case early motion protocols are instituted within 24 to 48 hours of surgery.

Rehabilitation
Extremity reconstructions usually require a period of occupational and physical therapy rehabilitation to optimize functional recovery. In upper extremity surgery, good compliance with physical therapy may account for up to 50% of the final functional outcome. Customized splint fabrication is important to support joints in their best functional positions to prevent deforming contractures. Paraplegic patients require careful instruction on pressure relief, both when in bed and when in their wheelchairs, because failure to relieve weight can cause recurrent ulceration in a matter of weeks or months, completely negating
the benefits of a reconstructive procedure. Careful inspection of wheelchairs and pressure-relieving cushions for malfunction is essential. As always, rehabilitation to a functioning position in society remains the ultimate goal of any reconstruction.

CONCLUSION
Surgical decision-making is complex and must be individualized for each patient and each clinical problem. Equal weight should be given to patient assessment, surgical planning, intraoperative execution, and postoperative care, because a deficiency in any one area may mean ultimate failure of the reconstruction. Although this text focuses on flap selection and execution, the importance these other areas cannot be overstated.

Bibliography With Key Annotations

Treatment of wounds has been the cornerstone of plastic surgery since its inception. Vacuum-assisted closure provides a new paradigm that can be used in concert with a wide variety of standard existing plastic surgery techniques. It was originally developed as an alternative treatment for debilitated patients with chronic wounds. It has rapidly evolved into a widely accepted treatment of chronic and acute wounds, contaminated wounds, burns, envenomations, infiltrations, and wound complications from failed operations. The ease of technique and a high rate of success have encouraged its adaptation by thoracic, general, trauma, burn, orthopedic, urologic, as well as plastic surgeons. This article discussed multidisciplinary advances in the use of the vacuum-assisted closure technique over the past 10 years and its status as of 2006. Creative surgeons continue to regularly adapt the system to difficult problems. This technique in trained surgical hands greatly enhances the scope and safety of wound treatment.


A short arm stump was lengthened with a composite flap with four different tissue units based on the subscapular artery.


Because of the increasing popularity of perforator flaps, many articles on their use have been published during the past few years. Because the area of perforator flaps is new and rapidly evolving, there are no definitions and standard rules on terminology and nomenclature, which creates confusion when surgeons try to communicate and compare surgical techniques. This article attempts to represent the opinion of a group of pioneers in the field of perforator flap surgery. This consensus was reached after a terminology consensus meeting held during the Fifth International Course on Perforator Flaps in Gent, Belgium, on September 29, 2001. It stipulated not only the definitions of perforator vessels and perforator flaps but also the correct nomenclature for different perforator flaps. The authors stated that this consensus is a foundation that can stimulate further discussion and encourage future refinements.


This article describes the successful treatment of an abdominal wall defect with a high-output enterocutaneous fistula associated with Crohn’s disease in a female patient using the wound vacuum-assisted closure system.

The chronic irradiated scalp wound remains one of the most difficult reconstructions for the plastic surgeon. With its inherent radiodermatitis and poor healing potential, chronic ulcers down to bone will result if coverage cannot be achieved. Reconstructive procedures as simple as a skin graft have a high complication rate in the irradiated wound and often fail. Local tissue transfer also has a high failure and complication rate because of the decreased vascularity of the wound bed and radiation damage to the surrounding scalp tissue, limiting one’s ability to manipulate it. The authors reported two cases using a simple method with Integra bilaminate skin substitute for repair of difficult wounds of the radiated scalp. Both patients were successfully treated using Integra. This simple method resulted in complete healing of the irradiated scalp wound and an acceptable, functional, and cosmetic outcome with minimal morbidity to the patients.


Descriptions of the reconstructive ladder permeate the literature and discussion of plastic surgery. The reconstructive ladder is a flawed concept, however. The principles and practice of plastic surgery may be better reflected in the phrase reconstructive elevator. The reconstructive elevator implies that in the era of form and function, simplest is not necessarily always best. To think sequentially about the best reconstruction options no longer suffices; technology and advanced techniques have made this type of thought obsolete. Reconstructive surgery calls for parallel, creative thought rather than simple sequential thought. One must be free to skip a rung of the ladder and take the elevator up to the next floor.


Compound flaps can be partitioned into two major classes that in turn are further differentiated into various subtypes according to their inherent pattern of circulation. Although many technical modifications have improved and will improve the reliability and versatility of compound flaps, these maneuvers alone should not be confused with creating distinct flap types but rather should be acknowledged as only important variations. With this understanding, this revised nomenclature system for compound flaps detailed by the author is intended to be a means of standardizing communication and to facilitate research agendas on a common ground, fully realizing its primary role still only to serve as a convenient guideline.


The unique niche for compound flaps is their potential role for the repair of massive defects that demands the simultaneous restoration of multiple, missing tissue types. These complex flaps can be sorted into two major classes, and their subtypes on the basis of their means of vascularization are described. (1) Solitary vascularization, the composite flap: “multiple tissue components with a single vascular supply and dependent parts.” (2) Combined flaps: (a) Siamese flaps: “multiple flap territories, dependent as a result of some common physical junction, yet each retaining their independent vascular supply”; (b) conjoint flaps: “multiple independent flaps, each with an independent vascular supply, but linked by a common indigenous source vessel”; and (c) sequential flaps: “multiple independent flaps, each with an independent vascular supply, and artificially linked by a microanastomosis.” Many technical modifications that have improved or will improve the reliability of these flaps should not be confused as distinct flap types, but rather acknowledged as variations that can be more conveniently classified for the purposes of improved communication and research by using this basic schema as a guideline.

The authors reported a method of elevating and rotating a flap like a propeller for the release of scar contractures. They obtained satisfactory results in the repair of scar contractures in the cubital and axillary regions. This flap may be applied to the flexor side in other regions, such as the groin, popliteal fossa, and fingers, where burn contractures are common.


Chimeric composite flaps, combined using microanastomoses, consist of two or more flaps or tissues, each with an isolated pedicle and a single vascular source. Free combined chimeric flaps using the lateral circumflex femoral system were used to treat massive composite defects of the head and neck in 10 cases. Combined anterolateral thigh flap and vascularized iliac bone graft based on the lateral circumflex femoral system and the deep circumflex iliac system was the most commonly used combination. An anteromedial thigh flap and a parambilical perforator-based flap were also combined with this principal combination. The advantages of this chimeric flap over other osteocutaneous flaps were reviewed.


The author discussed how the old concept of a length/width ratio for estimating skin flap length has gradually evolved into a new one: that flaps made under similar conditions of blood supply survive to the same length regardless of width. The steps of this change in concept were presented.


A tremendous amount of research has been conducted in recent years investigating the mechanisms of action by which the application of subatmospheric pressure to wounds increases the rate of healing. Similarly, numerous studies have also been conducted examining the physiologic response of wounds to the applied subatmospheric pressure. However, many more need to be conducted. A series of basic studies examining the use of subatmospheric pressure to treat wounds was presented, including the original studies on which the vacuum-assisted closure device was based (on blood flow, granulation tissue formation, bacterial dearance, and survival of random-pattern pedicle flaps). Subsequent studies analyzing removed fluids, envenomation/extravasation, burns, grafts, and in vitro tissue culture studies were also reviewed. Two broad mechanisms of action were proposed: removal of fluid and mechanical deformation. Fluid removal both decreases edema—thus decreasing interstitial pressure and shortening distances of diffusion—and removes soluble factors that may affect the healing process (both positively and negatively).


Sixteen cryopreserved inferior limbs were latex-injected in the femoral artery and the skin perforators of the distal anteromedial thigh and their source vessels were studied. In addition, from December 2000 to June 2005, skin islands from the distal anteromedial aspect of the thigh of six patients were transferred as local perforator flaps to reconstruct the peripatellar region and upper leg soft tissue defects. Every flap was based on a single adequate perforator vessel. The tissue was rotated, like a propeller, through 180 degrees. The authors called the flap the “propeller distal anteromedial thigh perforator flap.” This flap can be reliably transferred based on only one adequate perforator vessel. It reduces morbidity and improves the availability of the distal anteromedial thigh as a flap donor site and represents an additional reconstructive option for knee and upper leg defects.

The authors reported the consensus on the definition and classification of propeller flaps reached at the First Tokyo Meeting on Perforator and Propeller Flaps in June 2009. Some peculiar aspects of the surgical technique were discussed. A propeller flap can be defined as an “island flap that reaches the recipient site through an axial rotation.” The classification is based on the nourishing pedicle (subcutaneous pedicled propeller flap, perforator pedicled propeller flap, supercharged propeller flap), the degrees of skin island rotation (90 to 180 degrees) and, when possible, the artery of origin of the perforator. A flap should be called a propeller flap only if it fulfils the definition above. The type of nourishing pedicle, the source vessel (when known), and the degree of skin island rotation should be specified for each flap.


Perforator flaps have these advantages: reduced donor site morbidity, the versatility to accurately replace the components required at the recipient site, a longer pedicle than is achievable with the parent myocutaneous flap, and freedom from orientation of the pedicle. Their development has followed our understanding of the blood supply from a source artery to the skin, which has been achieved because of landmark studies by Manchot, Salmon, Milton, Taylor, and others. Many articles now attest to the safety and reliability of perforator flaps. This review outlined the history and controversies surrounding perforator flaps and described the anatomy of the workhorse perforator flaps and their use in microsurgical reconstruction. These flaps include the deep inferior epigastric artery, anterolateral thigh, thoracodorsal, and superior and inferior gluteal artery perforator flaps.


The data in this article provide profound insights into the mechanism of action of the vacuum-assisted closure device, providing an explanation for the increases in wound bed vascularity and cell proliferation based on its components. Results suggest that the vascular response is related to the polyurethane foam, whereas tissue strains induced by the vacuum-assisted closure device stimulated cell proliferation.


The authors proposed a new terminology for classification of the anterolateral thigh flap based on the “simplified nomenclature for compound flaps” introduced by Hallock. The intention of this new terminology is to describe both tissue components and skin vessel type. Anterolateral thigh flaps can be classified into two subgroups according to the tissue components, as follows: cutaneous or compound. The skin vessel types can also be classified into two subgroups according to the course they traverse: septocutaneous vessel or myocutaneous perforator. This classification may bring a consensus on the nomenclature of anterolateral thigh flaps and would be applicable to other perforator flaps.

The indications for free flaps have been more or less clarified; however, the course of reconstruction after the failure of a free flap remains undetermined. Is it better to insist on one’s initial choice, or should surgeons downgrade their reconstructive goals? To establish a preliminary guideline, the authors analyzed the outcome of 101 failed free tissue transfers of 3361 head and neck and extremity reconstructions performed by free tissue transfers. The authors concluded that a second free tissue transfer is, in general, a relatively more reliable and more effective procedure for the treatment of flap failure in the head and neck region, as well as failed vascularized bone flaps in the reconstruction of the extremities. Conservative treatment may be a simple and valid alternative to second (free) flaps for soft tissue coverage in extremities with partial and even total losses.


Various paradigms have been offered to describe the increasingly sophisticated methods of wound closure. The most established is, of course, the reconstructive ladder. The reconstructive ladder implies that the simplest technique should be explored before progressing up the rungs, and that should be done only when required. It has been dismissed by the champions of the second paradigm, the reconstructive elevator. The floors are equivalent to the rungs of the ladder, but with an elevator we can jump several floors and go straight to the floor/technique desired. The authors propose a new paradigm, the reconstructive stages. Instead of rungs or floors, they equate surgical techniques to stages. The next stage can only be attempted after the preceding one has been completed often enough so that one does not fail. Unlike the ladder or elevator, the reconstructive stages reflect the skill and effort required as the more difficult technique is adopted.
Chapter 2

Vascular Basis of Flaps and Flap Classification

Steven F. Morris
Peter G. Davison

Since the times of ancient civilizations, physicians have struggled to close traumatic wounds. The initial attempts were hampered by inadequate anesthesia, lack of antiseptics, and crude instruments. More recent challenges have included incomplete anatomic understanding and poor surgical technique. However, over the course of time, surgical ingenuity has resulted in a gradually improved ability to move tissues around the body to close wounds.

A flap may be defined as a vascularized tissue transfer. It can consist of skin, muscle, fascia, subcutaneous tissue, tendon, nerve, or any combination of these. It may be either pedicle based on an attachment to the donor site, or the flap may be detached completely and its vessels re-anastomosed at the recipient site. The history of the development of flaps in reconstructive surgery has been fairly haphazard and random.1 Initially, wound closure was achieved by primitive suturing techniques. Later, methods of skin grafting and local, regional and distant tissue transfers evolved. Often, excellent reconstructive techniques were identified but not effectively communicated so the surgical technique never became widely accepted. For example, Sushruta2 of India described nasal reconstruction using a delayed forehead rotation flap about 600 bc. This yielded excellent results and is a procedure that is still used with good results.

Fig. 2-1 Sushruta nasal reconstruction. Sushruta described this nasal reconstruction about 600 bc in the book Sushruta Samhita.
About 2200 years later, Gaspare Tagliacozzi described a delayed, tubed arm flap for nasal reconstruction in 1597. Survival of this multistage reconstruction relied on a random blood supply and yielded worse results than the forehead flap technique. It is interesting that the ancient “Indian rhinoplasty” technique was lost and replaced by an inferior random-pattern flap technique.

**Fig. 2-2** Gaspare Tagliacozzi nasal reconstruction, 1597.

**STUDY OF VASCULAR ANATOMY**
An understanding of vascular anatomy is crucial to the design of flaps of any kind. However, flap design in the early days of reconstructive surgery was hampered by an inadequate knowledge of vascular anatomy. Carl Manchot in the late 1800s and Michel Salmon in the 1930s were the first researchers to take an interest in the vascular anatomy of the skin and soft tissues.\(^3\)\(^4\) Manchot’s work\(^5\)\(^6\) from 1889 was largely unrecognized by the surgical community until it was translated from German into English. This was the first major study to describe the vascular supply to the integument; it also described in detail 40 cutaneous territories.

**Fig. 2-3** Carl Manchot’s illustration from his 1889 publication depicts the territories supplied by the cutaneous arteries of the human body.
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In 1936, Salmon’s publications expanded on this work. On the basis of a large number of angiographic studies using lead oxide, he defined more than 80 vascular territories throughout the body. Ironically, the research work of Manchot and Salmon provided important information regarding the vascular basis of flaps, yet this information was not recognized by surgeons of the era.

**Fig. 2-4** Michel Salmon’s vascular territories of the human body, from his book *Artères de la Peau.* The vascular territories are numbered and indexed.
Part I: Fundamentals

Ian Taylor and colleagues\textsuperscript{9-15} refined the lead oxide injection technique and used it to produce a vast body of anatomic work. This resulted in dozens of publications on vascular and neurovascular territories of the body and the vascular basis of flaps. This work was very closely related to surgical breakthroughs including the use of free tissue transfers\textsuperscript{16,17}, vascularized bone transfers\textsuperscript{18}, and the use of the Doppler for flap design\textsuperscript{19}. Cormack and Lamberty\textsuperscript{20-22} also contributed significantly to our current understanding of the vasculature of the human body. They provided detailed descriptions of the skin’s vasculature and differentiated between anatomic, dynamic, and potential territories. Cormack and Lamberty also used the lead oxide injection technique, which Salmon had initially reported. This injection technique was further defined by Taylor, Bergeron, and Tang\textsuperscript{23,24}

More recently, computerized axial tomography and advanced software have allowed three dimensional analysis of the vascular anatomy of regions of interest\textsuperscript{25-27}. This technique has allowed layer-by-layer analysis of the vasculature without disrupting the anatomy as in dissections. Three-dimensional vascular anatomic techniques and clinical imaging modalities provide a vast amount of useful anatomic information to the surgeon planning a reconstructive procedure.

Fig. 2-5 Cormack and Lamberty’s simplified concept of the underlying vasculature of anatomic, dynamic, and potential territories for flap design.

Fig. 2-6 A three-dimensional reconstruction that demonstrates the vascular anatomy of a deep circumflex iliac artery (DCIA) osteocutaneous perforator flap.
EVOLUTION OF FLAP DESIGN

Initially, surgeons used flaps almost exclusively to reconstruct soft tissue defects, so the flaps were usually skin-only flaps and were designed in a random fashion; that is, no effort was made to identify the vascular basis of the flap or to include vessels at the base of the flap. In fact, it was assumed at the time that the width of the flap determined the surviving length of the flap; the so-called length-to-width ratio. Stuart Milton\(^{28}\) disproved this theory with an elegant study using a porcine flank skin flap in which he compared flaps of differing widths and found equivalent survival. McGregor\(^{29,31}\) is credited with recognizing the importance of the distinction between random and axial flaps, which are supplied by major vessels running within the skin along the axis of the flap. In the 1960s and 1970s, the concept of the axial flap was used to design the deltopectoral flap based on the internal mammary perforators and the groin flap based on the superficial circumflex femoral vessels. When it was generally appreciated that the vascular anatomy of a flap influenced its survival, there was a flurry of activity in both the study of the anatomy of flaps and in the development of a wide array of skin, muscle, and bone flaps. Other axial flaps, including the forehead flap based on the supraorbital vessels, the postauricular flap based on postauricular vessels, and the dorsalis pedis flap based on the dorsalis pedis vessels were described.

Once axial-pattern flaps became widely used, the limits of viability of the flaps were tested. In efforts to improve the viability of axial-pattern flaps, surgeons sought to include fascia in the flaps. Several descriptions and classifications of fasciocutaneous flaps emerged, including those by Cormack and Lamberty\(^{20}\) and Nakajima et al.\(^{32}\) A variety of fasciocutaneous flaps were subsequently described including the radial and ulnar artery forearm flaps, the circumflex scapular artery flap, the medial plantar artery flap and the saphenous flap. With the careful attention to the vascular supply of tissues, it was soon noted that the vascular supply to muscles was far larger and more consistent than the skin vasculature. Muscle and myocutaneous flaps were subsequently introduced by McCraw, Arnold, Mathes, and Nahai to take advantage of this robust blood supply, bulk, and minimal donor site scarring.\(^{33-39}\) Muscle flaps became very popular and widely used in the 1970s and 1980s.

The introduction of free autologous tissue transfer using microsurgical vessel anastomoses marked a momentous innovation that opened a new landscape of possibilities for the reconstructive surgeon. Taylor and Daniel\(^{16,40}\) in 1973 published the first clinical application of a free composite tissue transfer with reanastomosis at a distant site and thereby coined the term
**free flap.** This first free flap was a groin flap based on the superficial inferior epigastric artery (SIEA) used for a large medial ankle defect. Defect reconstruction was no longer limited to the donor sites within an arc of rotation or by a multistaged delayed pedicled tube flap reconstruction. The emergence of free flap reconstruction was possible because of the simultaneous development of the operating microscope, microinstruments, and sutures.

The most recent development in flap surgery has been the use of perforator flaps. Perforator flaps are strictly defined as pedicled or free flaps based on myocutaneous perforators; however, the term *perforator flaps* has evolved to encompass the variety of skin flaps based on skeletonized vessels supplying the skin flap directly, whether the vessel is myocutaneous, septocutaneous, or fasciocutaneous in origin. We have previously documented the approximately 400 cutaneous perforators that provide the basis for perforator flap design. The rapid expansion of our understanding of the vascular anatomy of perforator flaps and their applications has highlighted the continued need for detailed anatomic knowledge for intelligent flap design. There has been a steady evolution of flap design based on ever-improving anatomic understanding, which has led to more sophisticated and elegant solutions for clinical problems.

The angiosome concept describes the vascular supply to specific three-dimensional blocks of tissue, including skin and deeper tissue layers. The concept was first described and named in 1987 by Taylor and Palmer, in “The vascular territories (angiosomes) of the body.” The term *angiosome* originates from the juxtaposition of the Greek words *angeion* (“blood vessel”) and *somite* (“sector of the body”). Taylor et al described the angiosome concept as an “anatomic concept with clinical implications.” The angiosome concept has significantly enhanced the understanding of the blood supply of tissue and has stood the test of time.

Angiosomes are three-dimensional composite blocks of skin and deep tissue that are supplied by a single source artery. The angiosomes are interconnected by smaller-caliber choke anastomotic vessels and true anastomotic vessels to form a continuous vascular network that
encompasses the entire body, broken up into distinct units, arranged in a distribution that resembles a jigsaw puzzle. The original work of Taylor and Palmer\(^9\) described 40 source arteries bilaterally. They indicated that many of these territories could be further subdivided, depending on the definition of a main source vessel. A recent study by Morris et al\(^3\) identified 61 distinct vascular territories, based on the analysis of three-dimensional CT angiography of lead oxide–injected cadavers. Others have further subdivided the vascular territories into smaller subunits.\(^12,14,41-43\) The important observation to keep in mind regarding vascular territories is that the architecture of the vascular territory influences the behavior of tissue transfers. It is also crucial to note that the detailed vascular anatomy of different vascular territories varies dramatically from individual to individual. The main source vessels remain constant; however, the individual perforators are highly variable when compared from side to side in the same individual and between individuals.

**Fig. 2-9** Taylor and Palmer’s vascular territories (angiosomes) of the body, based on 40 source vessels. Vascular territories of the integument of the skin are delineated according to the source vessel of the perforator. The angiosomes are numbered: 1, Thyroid; 2, facial; 3, buccal internal maxillary; 4, ophthalmic; 5, superficial temporal; 6, occipital; 7 deep cervical; 8, transverse cervical; 9, acromio-thoracic; 10, suprascapular; 11, posterior circumflex humeral; 12, circumflex scapular; 13, profunda brachii; 14, brachial; 15, ulnar; 16, radial; 17 posterior intercostals; 18, lumbar; 19, superior gluteal; 20, inferior gluteal; 21, profunda femoris; 22, popliteal; 22a, descending geniculate saphenous; 23, sural; 24, peroneal; 25, lateral plantar; 26, anterior tibial; 27, lateral femoral circumflex; 28, adductor profunda; 29, medial plantar; 30, posterior tibial; 31, superficial femoral; 32, common femoral; 33, deep circumflex iliac; 34, deep inferior epigastric; 35, internal thoracic; 36, lateral thoracic; 37, thoracodorsal; 38, posterior interosseous; 39, anterior interosseous; 40, internal pudendal.
Each angiosome is supplied by a source artery. Some source arteries give off a single cutaneous perforator that supplies the complete angiosome, such as the SIEA\(^3,4,44\). Nevertheless, most cutaneous territories are supplied by source arteries that branch into multiple variable cutaneous perforators, such as the deep inferior epigastric artery (DIEA)\(^45-47\). Therefore each angiosome may often be further subdivided into numerous cutaneous territories, supplied by cutaneous perforators branching from their associated source vessel. More recently, these subunits of angiosomes, the anatomic territories associated with cutaneous perforators, have been termed both a cutaneous angiosome and a perforator angiosome, which can be shortened to perforasome\(^48-50\). This is consistent with the angiosome theory, which initially stated that angiosomes can be subdivided\(^9\).

Adjacent cutaneous territories are connected by anastomotic vessels in all directions around the perimeter of angiosome. Taylor and Palmer\(^3,9\) found an average of 376 cutaneous perforators in the human body with a diameter of 0.5 mm or greater. Each of these vessels is interconnected with adjacent arterial territories by either smaller-caliber choke anastomoses or true anastomoses.
Fig. 2-11 Sites of an average of 374 dominant cutaneous perforators of 0.5 mm or greater as they emerge from the outer layer of the deep fascia, colored to match their source vessels. The majority of perforators are myocutaneous on the torso, piercing the muscles near their fixed attachments, whereas they are most often fasciocutaneous in the limbs, piercing the deep fascia between muscles, tendons, or bone (compare with Fig. 2-9).

In the integument, the choke anastomotic vessels are generally of smaller caliber, with a narrow lumen, the so-called choke vessels. However, these connections can alternatively be “true” anastomoses without any reduction in caliber; these are seen primarily in deeper tissues such as muscles or nerve trunks, or with the vessels that accompany cutaneous nerves. The latissimus dorsi muscle connections between the thoracodorsal and intercostal territories are an example. There is an analogous arrangement on the venous side, where adjacent territories are connected by oscillating, bidirectional veins. These avalvular veins regulate the flow and pressure to maintain venous drainage equilibrium between neighboring venosomes (venous territories).

Fig. 2-12 True versus choke anastomoses between neighboring vascular territories.
The most likely area for necrosis in an elevated flap is at the junctional anastomotic zone of the territories supplied by adjacent cutaneous perforators from adjacent vascular territories. However, it has been shown in animal studies and correlated with clinical data that one adjacent anatomic territory, radially in any direction, supplied by an independent cutaneous perforator, may be reliably included in the dissection of a cutaneous perforator flap.\textsuperscript{3,51} In some instances, a second territory beyond the junctional zone can be supported, particularly if there are “true” anastomoses instead of choke vessels present at the interface. Interestingly, this can be extended with a vascular delay procedure to allow recruitment of additional vascular territories in the flap.\textsuperscript{51-54} Cormack and Lamberty\textsuperscript{20} referred to these different descriptions of flaps as the \textit{anatomic, dynamic, and potential territories} (see p. 38).

**ARTERIAL VASCULATURE**

The arterial system supplies the entire body through a three-dimensional continuous network of interconnected vessels, divided into many vascular territories. The vascular territories are mostly interconnected through smaller-caliber choke anastomotic vessels, and to a much lesser extent, true anastomoses. The boundaries of cutaneous territories are generally marked by the junctional zones of smaller-caliber choke vessels on the arterial side and with bidirectional oscillating veins in the venous system. The interconnections between the vascular arcades also occur in the deeper tissues, including muscle, bone, and nerve.

Blood vessels that supply the integument can be classified as either direct or indirect cutaneous arteries. Direct vessels supply the skin directly from the source artery, piercing through the deep fascia or traveling to the skin via an intermuscular septum, and they often travel directly into the subdermal plexus as an axial vessel. The direct cutaneous arteries vary in length, caliber and density over different areas of the body. The indirect vessels (septocutaneous and myocutaneous perforators) primarily supply muscle and deep tissues, after which terminal branches give off cutaneous perforators to the skin. The classification of perforator arteries as direct or indirect is less clinically applicable than their ability to support a flap, based on the source vessel. The caliber, direction, and pattern of perforators to the skin are most relevant, because they affect flap viability.\textsuperscript{4} The distribution of individual vessels varies from subject to subject; hence preoperative evaluation of the size, direction, and territory of individual vessels will be important for flap survival.

**MATHES-NAHAI CLASSIFICATION OF FASCIA/FASCIOCUTANEOUS FLAPS**

*Fig. 2-13* Patterns of blood supply to the integument: direct and indirect vessels. Patterns of blood supply to integument. Type A is a direct cutaneous pedicle; type B (septocutaneous) and type C (myocutaneous) are indirect cutaneous pedicles.
There are numerous cutaneous perforators within each vascular territory that supply the skin. The source vessels that supply an angiosome are the named main vessels, which are predictable and relatively consistent between individuals. However, there is great inter-individual variability in the number and arrangement of the specific perforator vessels that supply the skin of each territory, composed of both direct and indirect vessels.4

Taylor described a number of general principles that guide the clinical use of the angiosome theory, as follows.3,9,10

**Law of Equilibrium**
A balance or equilibrium of blood supply to adjacent territories is maintained so that a dominant supply from one cutaneous perforator is balanced by a smaller size of a neighboring perforator within an angiosome or in adjacent angiosomes.7 In other words, there is an inverse relationship between adjacent individual perforators that supply the same region.7,8 When small vessels are found in one area, larger vessels are present adjacently.9 This law of equilibrium was initially recognized by Salmon in 19367 and was put into clinically relevant terms by Taylor.9 For example, the calibers of the SIEA and DIEA tend to be inversely proportional, as seen when elevating a DIEA flap (see p. 42). This becomes important clinically when evaluating which potential perforator or source vessel to include in a flap. For example, if the SIEA is particularly large, the DIEA perforators may be correspondingly smaller.

**Vessels Move From Fixed to Mobile Skin**
Perforators pierce the deep fascia at areas of fixed skin and then are oriented from areas of fixed to mobile skin.

- Areas of fixed skin correspond to the locations at which the deep fascia is “anchored to bone or to the intermuscular and intramuscular septa.”
- Vessels flow toward the convexities of the body.
- In areas with fixed skin, such as the palms and soles, there will be a higher density of short perforator branches.
- Areas of mobile skin are supplied by fewer, longer perforator branches; for example, in the torso—the deltopectoral flap. Other regions with fewer, longer perforators include the arm, thigh, head, and neck.

Arterial vessels are also long when they travel in association with a cutaneous nerve. In general, cutaneous vessels in areas of loose skin have a larger vascular territory.

**Vessels Follow Connective Tissue Framework**
The body is composed of a continuous framework of rigid and loose connective tissue, including bone and fascia. The network of arteries and veins follows these connective tissue planes as they radiate from the heart to the periphery. Proximally, vessels generally travel close to the axial skeleton, then branch into the intermuscular septa, then give off smaller branches to supply the muscles and other deep tissue. It is noteworthy that the vessels may travel next to but not truly within the septa as they perforate a muscle. The terminal branches of the arteries and their associated venae comitantes take off from their source vessels and pierce the deep fascia as they follow the superficial fascial planes up to the integument.

**Growth and Development**
During the early stages of human embryonic development, the mesoderm forms the mesenchyme—connective tissue that further differentiates into bone, cartilage, fascia, the lymphatic system, and the vascular system. Therefore, after completion of growth and differentiation, the blood vessels are left in the surroundings and tissue planes of the rigid and loose connective tissue, including the intermuscular and intramuscular septa. This intuitively explains the
vascular anatomy of vessels that follow the connective tissue framework. Hunter posited a fixed number of arteries in the body. The cutaneous perforators in the fetus branch off in a stellate pattern. In the regions where there has been longitudinal growth in that direction, these will develop into axially oriented vessels in adults.

**VENOUS VASCULATURE**

The study of the venous structures of the body has attracted less interest and is more difficult than the study of the arterial anatomy. Generally, it is assumed that venous structures mirror the arterial anatomy; however, there are important differences. Our understanding of the venous vasculature was significantly advanced from the landmark study on venous territories published by Taylor et al in 1990 (see p. 41). This study outlined the entire venous system with meticulous detail throughout the human body’s integument and deep tissues. Using refined techniques of retrograde intravenous injection of chlorocresol and lead oxide, six cadavers were precisely dissected and radiographed. All perforating veins of the integument were identified and tagged. Additionally, the superficial and deep veins were microscopically dissected to classify valvular and avalvular veins and thereby understand the patterns of venous drainage. The authors found that analogous to the arterial vasculature, the venous system throughout the body is made up of venous territories (venosomes) that form a vast, three-dimensional, interconnected network of veins. These arcades of veins exist within and between all tissues. They are the link between adjacent vascular territories. The flow of venous drainage is directed from the capillary level, with increasing caliber of vessels as they converge at the superior and inferior venae cavae.

**Network of Arcades**

The venous vasculature comprises superficial and deep systems. Superficial veins are generally independent of the arterial vasculature, and their territory of drainage may cross multiple angiosomes. Superficial veins are located in the subdermal plexus, are larger than venae comitantes, and flow axially in the limbs. Examples include cephalic, basilic veins in the upper extremity; and the saphenous vein in the lower extremity. Veins in the deep system, venae comitantes, generally parallel their associated source artery and its perforators. In some regions, venae comitantes are paired; in other regions, they are single. The horizontal superficial veins are connected to the deep system throughout their course either via the venae comitantes or the larger-caliber valvular venae communicantes. Contrary to earlier findings by Schafer, Taylor et al found that the integument is primarily drained by venous vasculature that parallels the arterial system, the venae comitantes. Certain regions of the limbs are the exception.

**Valvular and Avalvular Connections**

The veins throughout the body are either valvular or avalvular, which thereby determines the possible direction of blood flow. The superficial veins that make up the horizontal channels in the limbs and veins are arranged in a stellate pattern. The venae comitantes that collect blood from a vascular territory parallel to the arterial system, such as a cutaneous perforator or muscle pedicle, are also directional, valved veins. These veins are arranged in a treelike pattern that has valves along the branches, at the branching points off the trunk, and at the entry of the pedicle into the parent vein. However, the distalmost tips of these venous branches have no valves and are therefore bidirectional. These smaller collecting veins will be continuous with those of the adjacent venous tree, whose venous branches will have valves oriented in the opposite direction.
One of the key concepts discovered by Taylor et al\textsuperscript{10} in their venosome study was the presence of interconnected valvular and avalvular channels within the venous system that maintain an equilibrium of flow (and possibly pressure) between adjacent vascular territories. Analogous to the choke vessels that mark the perimeter of cutaneous territories, there are oscillating, bidirectional veins that maintain equilibrium in the vascular drainage. These avalvular vessels define the boundaries between adjacent venous territories.

**Veins Converge From Mobile to Fixed Areas**

The deep veins travel within the connective tissue framework, along with their accompanying arteries from the heart to the integument. Generally, veins are oriented parallel to the plane of mobility and only cross mobile tissue planes at areas where the skin is adherent to underlying fascia or bone.\textsuperscript{10} Mobile tissue planes are relatively avascular.

Veins course from areas of mobile skin to fixed skin. Similar to arteries, they will perforate the deep fascia from the subcutaneous tissue at locations where the two structures are anchored together. Taylor et al\textsuperscript{10} mapped the common locations of venous perforators, which include the perimeter of muscles, intermuscular septa, flexor surfaces of joints, dorsal and ventral midline, base of the skull and orbital margins (where the galea is anchored), and areas of deep fascia fixation to bone.
Muscles Propel Venous Return
Similar to the arterial system, the venae comitantes may drain the integument directly or indirectly, based on their course either through intermuscular septa or intramuscular septa, respectively. When paired, the venae comitantes are generally connected with their mirrored vein via a valvular channel in a stepladder pattern. Venae comitantes are efferent veins; they drain the muscles toward the venae cavae. Afferent veins drain blood into nearly all muscles of the body from the surrounding tissues, which may include the overlying integument, adjacent muscles, and the bone or bones of the muscle’s insertion or origin. The venous cutaneous perforators are generally directional and valvular, whereas the intermuscular venous arcades are primarily avalvular. Muscle contraction is of prime importance for venous blood return, because this “pumps” the blood back toward the heart.

NEUROVASCULATURE
The high volume of trauma from the two world wars resulted in many peripheral nerve injuries. At the time the management of these injuries was limited, largely because of an incomplete understanding of peripheral nerve anatomy and physiology. A lifetime of productive research by Sir Sydney Sunderland greatly advanced our knowledge of the subject.

One of the key anatomic concepts noted by Taylor et al during their studies on arterial and venous vasculature to the integument is that there is a close relationship between vessels and nerves; as they described it: “Vessels hitchhike with nerves.” This relationship was evaluated in detail in subsequent work, in which the neurovascular territories of the skin and muscles were described. Human cadavers underwent total body injection of a radiopaque lead oxide mixture into either the arterial or venous system. The integument and many of the muscles were removed and radiographed. Second, the cutaneous nerves and extramuscular and intramuscular course of motor nerves were dissected. Labeled with multifilament computer wire, the nerves could then be radiographed. Subtraction radiography allowed the wire-labeled nerves to be isolated from the injected vasculature.

Cutaneous Nerves
Taylor et al found that all cutaneous nerves were accompanied by an artery—either one continuous artery or a chain-linked system of arteries. However, the reverse is not always the case; some major cutaneous arteries had no accompanying cutaneous nerve. It was also noted that nerves are economical: they travel the shortest distance between two points. Arteries and cutaneous nerves often travel together as they course from the deep tissue, pierce through the deep fascia, and enter the integument, generally at areas of fixed skin. However, multiple patterns were noted of the relative locations that a cutaneous nerve and the associated artery pierce the fascia. At certain locations, the nerve and artery traverse the fascia at a distance from one another and unite distally. Alternatively, a nerve may diverge from its accompanying artery after emerging through the fascia and travel with another artery more distally.
Chapter 2  •  Vascular Basis of Flaps and Flap Classification

Motor Nerves
Taylor et al. evaluated the neurovascular patterns of 80 different muscles in their cadaver study. They noted several key concepts about motor nerves:

1. Nerves follow the connective tissue framework. From the nerve origin, the motor nerve travels within a connective tissue sheath until it reaches the neurovascular hilum of the muscle. Within the muscle, the nerves follow the intramuscular connective tissue.

2. Nerves are economical. Analogous to the cutaneous nerves, motor nerves travel the most direct extramuscular and intramuscular route, from their origin at the spinal cord to their target muscle that permits functional muscle contraction. Nerves approach the proximal aspect of the muscle, with respect to the nerve origin at the spinal cord. Intramuscular nerve fibers are oriented parallel to the muscle bundles.

3. Nerves enter the muscles in the direction of their geometric center. This was first noted by Schwalbe in 1879, who also described a morphologic muscle classification with three groups, based on muscle shape. The neurovascular relations vary based on the muscle and the extramuscular and intramuscular nerve architecture. Muscles may have a single nerve supply or multiple motor nerves. There were several key findings by Taylor et al.:
   A. Motor nerves have an accompanying vascular pedicle. However, many vessels have no associated nerve.
   B. Generally, the motor nerve accompanies the dominant vascular pedicle
   C. The nerve may branch just before entering the muscle, forming a neurovascular hilum, or afterward.
   D. A motor nerve divides early after entering the muscle, and its branches rapidly orient themselves parallel to the muscle fibers.

4. The law of equilibrium, as discussed earlier, states that a reciprocal relationship exists between adjacent territories with respect to vessel caliber. Analogously, there is a reciprocal relationship between multiple motor nerve branches that supply a muscle in terms of the size and the number of nerve branches to the muscle from the same nerve trunk.
Muscle Classification

Muscles can be classified based on several features, including shape, morphology, function, blood supply, and nerve supply. It is important to understand the pattern of motor innervation of muscles to harvest functioning muscle transfers or to maintain function in a muscle after harvesting a segment of this muscle. For example, biceps femoris has two separate nerve branches and is therefore suitable for segmental harvest, leaving the remaining portion innervated.

Muscle Nerve Classification

Taylor et al\textsuperscript{11} described the following muscle innervation types:

- **Type I** Muscle supplied by single motor nerve that divides after entering the muscle
- **Type II** Muscle supplied by a single motor nerve that divides before entering the muscle
- **Type III** Muscle supplied by multiple nerve branches that originate from the same motor nerve trunk
- **Type IV** Muscle supplied by multiple motor nerves that originate from different nerve trunks

Types II, III, and IV can be subdivided into separate neurovascular units and partially harvested as a flap for local or distant transfer, leaving a functional muscle in situ. Especially for types III and IV, this dissection is relatively straightforward; the multiple neurovascular pedicles can be isolated before entering the muscle. However, with a meticulous intramuscular dissection of the motor nerve branches, it is also possible to elevate a portion of a type I muscle as a flap without denervating the residual fibers.

![Fig. 2-16](https://example.com/muscle_classification.png)

**Fig. 2-16** Muscle classification based on motor nerve supply. Type I: single unbranched motor nerve; type II: single motor nerve branched before entering muscle; type III: multiple motor nerve branches from same nerve trunk; Type IV: multiple motor nerve branches from different nerve trunks.
DELAY PHENOMENON

During World War II, the tubed pedicle flap was used increasingly to transfer tissues to distant sites. This technique is based on a random-pattern flap where the tissue is rotated about the pedicle base and attached distally to a new site, possibly an arm carrier. The delay of these random flaps relied on the subdermal vasculature to adapt and revascularize from the new site of attachment. The delay of these random-pattern flaps improved the survival of the flaps. Later, the flap would be rotated again, based on the opposite flap tip. With the use of multiple delays or an arm carrier, complex reconstructions of distant sites were possible long before the introduction of microvascular free flaps. Today this reconstructive approach is essentially of historical interest only. However, the tubed flaps led to an awareness and understanding of the delay phenomenon, which is the basis for delayed flaps.

The delay phenomenon is based on the physiologic events that follow a partial restriction in blood flow to tissue. It is possible to delay both skin and muscle flaps. For example, a flap may be partially elevated or its blood supply partially ligated, which stimulates vascular events within the flap that lead to increased flap vascularity based on the planned pedicle. The purpose of the delay technique is to increase the size of flap and/or its vascularity and reliability. It has been shown that a flap can be safely raised in one cutaneous territory, and one adjacent territory can generally be recruited. The delay phenomenon is the only documented technique that can reproducibly extend the zone of perfusion to a second or third cutaneous vascular territory beyond that supplied by the cutaneous perforator at the base of the flap. When an undelayed flap is raised, the demarcation line of necrosis has generally been in the junctional choke zone at the outer perimeter of the adjacent vascular territory. Therefore the limiting factor of viable flap dimensions depends on the spacing of cutaneous perforators. Areas of fixed skin have a high density of vessels emerging from the deep fascia; mobile areas have a much greater distance between perforators. For example, the deltopectoral flap based on the internal mammary perforators has a large, reliable area of vascular supply without delay.

Fig. 2-17  The area of necrosis (shaded) if the flap is raised based on isolated vascular supply with A, no delay; B, single-stage delay of vessel 1; C, delay of vessels 1 and 2. In C, vessel 3 will be divided at the second stage to allow a long pedicled flap based on the base of the flap.
Delay Technique
There are many variations on techniques for surgical delay. The flap may be partially incised, partially elevated, or one or more adjacent vessels can be ligated. If the surgical margins of the planned flap are partially incised, the planned vascular supply of the flap is left intact. As a result, the choke vessels of the first junctional zone irreversibly dilate. The caliber of vessels increases so that they become more like true anastomoses across the choke zone. This process results from hyperplasia of the blood vessel wall cells, as well as hypertrophy and elongation. The maximal dilation is seen by 48 to 72 hours after the delay.

Clinically, delaying the elevation of a pedicled transverse rectus abdominis myocutaneous (TRAM) flap is an effective way to safely raise a large skin paddle. In the first stage, the superficial and deep inferior epigastric vessels are ligated. This provides a more robust vascular supply to the flap for the second stage, when the pedicled flap is raised definitively based on the superior epigastric vessels. The delay procedure is a reliable method for augmenting flap survival in challenging situations.

Fig. 2-18 Strategic delay of a pedicled TRAM flap, shown here for intended left breast reconstruction. A, The original anatomy is shown, with the identified DIEA and SIEA vessels that supply the skin island of the designed TRAM flap. B, Ligation of the DIEA vessels bilaterally and the ipsilateral SIEA vessels.

Dominant pedicles to rectus muscle: Superior deep epigastric artery and associated venae comitantes (D1); deep inferior epigastric artery and associated venae comitantes (D2)

Dominant pedicle to fasciocutaneous inferior abdominal region: Superficial inferior epigastric artery and associated venae comitantes (D3)
FLAPS/SKIN FLAPS

A flap is a vascularized tissue transfer. It may include any tissue type and may be based on a pedicle as a local or regional flap or may be transferred distantly microsurgically by microvascular anastomoses. A skin flap is a vascularized skin transfer. Vascularity is intrinsic and may be maintained at the flap base, as in a pedicled skin flap, or reconnected to vessels at the recipient site using microsurgical techniques, as in a free microvascular skin flap. A comprehensive summary of skin flap surgery including the history and anatomy was published by Cormack and Lamberty in 1986.20

Local Flaps

Random

The earliest flaps were random-pattern flaps.29 These flaps are considered random because their maintained vascular supply is not based on a named vessel; they are supported by a random arrangement of subdermal vasculature. They were so-named because of a lack of understanding of the vascular supply to the flap. Random-pattern flaps are useful for the reconstruction of small defects but have several inherent limitations:

- Proximity of the defect must be within arc of rotation
- There may be compromised vascularity in the associated zone of injury surrounding the wound
- Unpredictable survival

Rotation, transposition, advancement, and other geometric flaps are generally considered random-pattern flaps, although outcomes are improved by maintaining small perforating vessels in the base of the flap. The survival of small local flaps can be improved by the surgeon’s knowledge of the underlying vascular anatomy.

Rotation Flaps

Rotation flaps are local skin flaps in which skin and subcutaneous tissue is elevated and rotated in an arc from a pivot point at the flap base. The flap must be designed such that there is sufficient flap length to cover the most distal aspect of the defect, limited by the skin tension from the pivot point at the flap base to its tip. One must plan for the flap tip to extend beyond the arc of rotation of the distal defect to account for the length that will be lost due to the rotation. The donor site may be closed by primary closure, a local flap or a skin graft.

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**Fig. 2-19**

Semicircular flap is designed after triangular resection

Flap is undermined and advanced into defect; mobilization of the surrounding tissues allows closure of defect created by flap advancement

Tension-bearing part of random flap is most ischemic and most at risk for necrosis or dehiscence
Transposition Flaps
There are several versatile geometric patterns of transposition flaps that are commonly used for small defect closure, such as following skin cancer excision. The bilobed flap is an example of a transposition flap, where a smaller secondary flap is rotated to fill the defect from the primary flap that is used to reconstruct the defect. The Limberg or rhomboid flap is another useful transposition flap.

Advancement Flaps
Advancement flaps are accomplished by moving a flap of skin directly into a defect by the use of undermining but without any rotation, relying on the skin elasticity. The single pedicle advancement flap remains attached at its base and the skin is stretched forward directly into the defect. Excising Burrow’s triangles at each side of the flap base simplifies the closure along the sides of a rectangular advancement flap. The V-Y advancement flap is a common modification that can be useful for various wound reconstructions, such as volar fingertip soft tissue injuries.66,67

Fig. 2-20 A, Simple transposition. If transposed over a larger distance, a small triangle may be excised at the tip of the donor site to facilitate primary closure. B, Rhomboid flap. Note that any of the four corners could be elevated and rotated to fill the defect.

Fig. 2-21 The skin is elevated as a triangular island flap and advanced forward to fill the defect.
**Axial Flap**

An axial-pattern skin flap is designed according to the trajectory of the vessels supplying the flap. In 1973, McGregor and Morgan\(^\text{29}\) proposed the differentiation of skin flaps into two types, the random- and axial-pattern flaps. They defined an axial flap as “a single pedicled flap which has an anatomically recognized arteriovenous system running along its long axis.” The flap is designed such that the pedicle axis is aligned with the arc of rotation. This allows much greater sized skin flaps to be used. A workhorse flap for nasal tip reconstruction is the paramedian forehead flap. This axial flap is based on the dominant supratrochlear, and minor supraorbital vessels. The deltopectoral flap is an example of a remarkably large axial skin flap that has many uses for skin coverage in the neck and lower face.\(^\text{68,69}\) The deltopectoral flap is based on the second and third anterior intercostal perforators.

![Fig. 2-22](image)

**Fig. 2-22**  Axial-pattern groin flap rotated to the lower abdomen, based on the superficial circumflex iliac artery (SCIA).

<table>
<thead>
<tr>
<th>Flap</th>
<th>Vascular Supply</th>
<th>Size (cm)</th>
</tr>
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<tbody>
<tr>
<td>Deltopectoral(^\text{69,72})</td>
<td>First to third rib perforators from internal mammary artery and venae comitantes</td>
<td>10 $\times$ 20</td>
</tr>
<tr>
<td>Paramedian forehead(^2)</td>
<td>Supratrochlear artery and venae comitantes</td>
<td>8 $\times$ 6</td>
</tr>
<tr>
<td>Abbé or reverse Abbé</td>
<td>Superior or inferior labial artery and venae comitantes</td>
<td>One fourth of lip?</td>
</tr>
<tr>
<td>Nasolabial</td>
<td>Transverse facial artery and venae comitantes</td>
<td>2 $\times$ 5</td>
</tr>
<tr>
<td>Standard forehead</td>
<td>Superficial temporal artery and venae comitantes</td>
<td>22 $\times$ 7</td>
</tr>
<tr>
<td>SIEA</td>
<td>Superficial inferior epigastric artery and vein</td>
<td>15 $\times$ 30</td>
</tr>
<tr>
<td>Groin</td>
<td>Superficial circumflex iliac artery and vein</td>
<td>10 $\times$ 25</td>
</tr>
<tr>
<td>Dorsal metacarpal</td>
<td>Dorsal metacarpal artery</td>
<td>1 $\times$ 4</td>
</tr>
<tr>
<td>Digital</td>
<td>Digital artery</td>
<td>6 $\times$ 1</td>
</tr>
</tbody>
</table>
FASCIA AND FASCIOCUTANEOUS FLAPS

Esser\textsuperscript{70} in 1917 and Gillies\textsuperscript{71} in 1920 had both suggested that including deep fascia in a random-pattern skin flap would be beneficial. Unfortunately, for many years this hypothesis was overlooked. In the decades that followed, skin flap design was guided by the now obsolete concept of length to width ratio limitations. Distant reconstruction was accomplished with delayed flaps and pedicled-tubed flaps, which comprised of skin and subcutaneous fatty tissue only. In the 1960s, Bakamjian et al\textsuperscript{69,72,73} reported good success with head and neck reconstruction using the large, pedicled deltopectoral flap. Reminiscent of earlier surgeons such as Esser\textsuperscript{70} and Gillies,\textsuperscript{71} Bakamjian et al\textsuperscript{73} advised the inclusion of deep fascia in deltopectoral flaps. In 1974, Bowen\textsuperscript{74} described including the deep fascia in ipsilateral lower leg flaps for large full thickness leg defects. Similarly, McGregor\textsuperscript{31} in 1975 noted that the deltopectoral flap could be extended by including the fascia. However, the generalized concept of the fasciocutaneous flap was not described until 1981, by Ponten.\textsuperscript{75,76} Ponten published a series of 23 lower leg defect reconstructions using an undelayed fasciocutaneous flap. They were successful in all but three patients, who had flap failure. Thereafter, fasciocutaneous flaps gained popularity as a reliable technique to cover bone and tendon in the lower leg and elsewhere.\textsuperscript{77} The clinical implications of the fasciocutaneous flap were further elaborated by Tolhurst et al\textsuperscript{77} in 1983, with a clinical series of 27 consecutive and successful reconstructions of a variety of defects on the lower leg and trunk. The following year, the classification of fasciocutaneous flaps based on their vascular pattern was established by Cormack and Lamberty.\textsuperscript{76} In 1997, Mathes and Nahai\textsuperscript{55} described a different fascial and fasciocutaneous flap classification based on the vascular anatomy of the pedicles to the integument.

A fascial or fasciocutaneous flap is elevated based on the deep fascial layer and its associated blood supply. A fasciocutaneous flap, which includes the skin, subcutaneous tissue, and the underlying fascia, provides a sturdier construct than an isolated fascial flap. The circulation of the deep fascia is based on the vascular pedicles that enter its deep surface and form a vascular plexus within the fascial plane that subsequently supply the overlying integument. The venous component of the pedicle is usually the paired venae comitantes that accompany the artery from the source vessels.

A major benefit of a fasciocutaneous flap in comparison to a myocutaneous flap is that it provides a robust vascularized skin flap without the expenditure of a functional muscle from the donor site, and without the often unnecessary bulk of a myocutaneous flap. Fasciocutaneous flaps are preferred in reconstructing areas in which the skin or mucosa at the wound is thin; for example, the lower leg, dorsum of the hand, nasal lining, and oropharynx. Similar to muscle flaps, fasciocutaneous flaps provide large blocks of tissue for defect reconstruction without the need for prior delay but are limited by the arc of rotation of the vascular pedicle, unless transferred as a free flap.

With our improved knowledge of vascular anatomy today, the indications for using a true fasciocutaneous flap in wound reconstruction are limited and depend on the donor site anatomy. Where the skin is relatively fixed to the underlying fascia, the integument is best raised as a fasciocutaneous flap because there will be many small perforators throughout the territory, supplying the skin. Conversely, where the skin is mobile with respect to the underlying connective tissue, then there will be sparse cutaneous perforators piercing through or traveling within the deep fascial plane. In the latter, there is negligible benefit to include the fascial layer when raising a cutaneous flap.
Cormack and Lamberty Classification of Fasciocutaneous Flaps

Cormack and Lamberty\textsuperscript{21,76,78,79} conducted a series of injection studies to further outline the vascular anatomy at the fascial level, identify the locations of fasciocutaneous perforators and fascial vascular plexuses, and postulate potential new fasciocutaneous flaps. They applied these anatomic findings clinically, with the implementation of fasciocutaneous flaps. Based on their combined experimental and clinical observations, they proposed a classification with four distinct types of fasciocutaneous flaps, differentiated by their vascular anatomy.

**Fig. 2-23** Cormack and Lamberty’s classification of fasciocutaneous flaps. Type A flaps have multiple fasciocutaneous vessels entering at the base of the flap that are oriented longitudinally within the flap and parallel to the direction of the arterial plexus. Type B flaps are based on a single fasciocutaneous perforator. Type C flaps are supported by multiple small perforators that arise from a main source vessel, passing along a fascial septum between muscles. Type D flaps are osteomyofascial cutaneous free tissue transfers.
**Type A**
The flap is supported by multiple fasciocutaneous perforator vessels at the flap base and orientated along the longitudinal axis of the flap, which is determined by the arterial plexus within the deep fascia. This pedicled flap may be based either proximally or distally, or as an island flap; for example, upper arm flaps based on the medial or lateral intermuscular septum.

**Type B**
The flap depends on a single dominant fasciocutaneous perforator that supplies the deep fascial vascular plexus. These perforators generally have a consistent location and may be raised as a pedicle or free flap; for example, antecubital forearm flap.

**Type C**
The flap is based on the fascial plexus supplied by multiple small perforators along the length of a fascial septum. The supplying artery is taken in continuity with the fascial septum and integument. It may be pedicled, based distally or proximally or used as a free flap; for example, the radial forearm flap.

**Type D**
Similar to type C, the type D flap is based on multiple small perforators, but it is raised as an osteomyofasciocutaneous flap. The fascial septum and the source artery are taken in continuity with the bone and adjacent muscle; for example, the radial forearm flap with half of the radius longitudinally.

**Nakajima Classification of Fasciocutaneous Flaps**
Nakajima et al\(^3\) described a classification of six types of deep fascia perforators based on patterns of perfusion. They conceptualized a three-dimensional framework of the fascial plexus and showed the various patterns of vascularization of the fascia. They reported that the body’s fascial vascular supply could be divided into these types: (1) direct cutaneous branch of muscular vessel, (2) septocutaneous perforator, (3) direct cutaneous vessel, (4) myocutaneous perforator, (5) direct septocutaneous and, (6) perforating cutaneous branch of muscular vessel.

![Fig. 2-24](image_url)  The six distinctive deep fascia perforators according to Nakajima et al. A separate type of fasciocutaneous flap could be named after each different perforator. (A, Direct cutaneous branch of a muscular vessel; B, septocutaneous perforator; C, direct cutaneous; D, myocutaneous perforator; E, direct septocutaneous; F, perforating cutaneous branch of a muscular vessel.)
Mathes and Nahai Classification of Fasciocutaneous Flaps

In 1997, Mathes and Nahai\textsuperscript{55} published a different classification of fascial flaps, also based on the pattern of vascular supply to the integument overlying the fascia. The three distinct types of vascular pedicles are direct cutaneous, type A; septocutaneous (intermuscular), type B; and myocutaneous (intramuscular), type C. The dominant vascular pedicles to the deep fascial plexuses of specific flaps were identified on anatomic dissections of deep fascia in humans using regional vascular injections of colored barium–latex solution.\textsuperscript{55} This is the classification that is used in this book.

### Examples of Useful Fascial Flaps

<table>
<thead>
<tr>
<th>Flap</th>
<th>Vascular Supply</th>
<th>Pattern of Circulation</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporoparietal fascia</td>
<td>Superficial temporal artery and vein</td>
<td>Type A</td>
<td>12 × 9</td>
</tr>
<tr>
<td>Reverse sural\textsuperscript{80}</td>
<td>Superficial sural artery and vein (retrograde)</td>
<td>Type A</td>
<td>8 × 12</td>
</tr>
<tr>
<td>Scapular</td>
<td>Circumflex scapular artery and venae comitantes</td>
<td>Type B</td>
<td>20 × 7</td>
</tr>
<tr>
<td>Radial forearm\textsuperscript{81}</td>
<td>Radial artery and cephalic vein and venae comitantes</td>
<td>Type B</td>
<td>10 × 40</td>
</tr>
<tr>
<td>Lateral arm</td>
<td>Radial collateral and venae comitantes</td>
<td>Type B</td>
<td>20 × 7</td>
</tr>
<tr>
<td>Anterolateral thigh\textsuperscript{82}</td>
<td>Descending branch of lateral circumflex femoral artery and venae comitantes</td>
<td>Type B and C</td>
<td>9 × 22</td>
</tr>
<tr>
<td>Submental artery</td>
<td>Submental artery and vein</td>
<td>Type C</td>
<td>7 × 18</td>
</tr>
</tbody>
</table>

**Type A: Direct Cutaneous Pedicled Flap**

The vascular pedicle enters the fascia from the deep surface and then travels for a variable distance in this plane. Distally, the vessels will pierce the fascia, branch out into the subdermal plexus and subsequently supply the integument. Along the length of the pedicle, multiple perforators supply the skin. The pedicle itself is generally long and superficial, traveling in a radial fashion, similar to that of an axial flap. Its course can often be readily identified by palpation and Doppler probe; for example, the deep external pudendal artery, digital artery, dorsal metacarpal artery, gluteal thigh, great toe, groin, lateral thoracic (axillary), pudendal-thigh, saphenous, scalp, second toe, standard forehead, superficial external pudendal artery (SEPA), superficial inferior epigastric artery (SIEA), sural artery, and temporoparietal fascia.
**Type B: Septocutaneous (Intermuscular) Pedicled Flap**
The vascular pedicle that supplies this fasciocutaneous flap courses from the source vessel to the skin either within a recognized intermuscular septum or in the space between adjacent muscles. This category was designed to encompass a broader range of fasciocutaneous flaps than the Cormack and Lamberty classification to simplify flap classification. The largest septocutaneous pedicles are dominant pedicles to specific fasciocutaneous flaps; for example, the anterior lateral thigh (ALT), anterior tibial artery, deltoïd, dorsalis pedis, inferior cubital artery, lateral arm, lateral plantar artery, lateral thigh, medial arm, medial plantar artery, medial thigh, peroneal artery, posterior interosseous, posterior tibial artery, radial forearm, radial recurrent, scapular, and ulnar recurrent.

**Type C: Myocutaneous (Intramuscular) Pedicled Flap**
The vascular pedicle for type C flaps originates from a large myocutaneous perforator that provides the blood supply to the muscle, en route from the source vessel to the deep fascial plexus and the integument. These dominant perforating vessels are therefore defined as indirect cutaneous perforators. The overlying skin can be supported by a fasciocutaneous flap with or without inclusion of the underlying muscle. Adequate pedicle length for a type C fasciocutaneous flap will generally require dissecting the pedicle back through its intramuscular course to the source vessel, ligating the side branches that supply the muscle. Unlike the other two fasciocutaneous flap types, these flaps have much greater variability in perforator locations and caliber; for example, ALT, deltopectoral, nasolabial, median forehead, thoracoepigastric, transverse back, and DIEA.

**MUSCLE FLAPS**
The discovery of muscle and myocutaneous flaps was a major advance in reconstructive surgery.33–39 Iginio Tansini described the latissimus dorsi flap in 1906 for postmastectomy reconstruction35; however, muscle flaps were not widely implemented clinically until the 1970s.35,83,84 Muscle and myocutaneous flaps were found to have a robust blood supply and were used to reliably reconstruct challenging soft tissue defects. It was noted that the vascular supply of skin transferred with a myocutaneous flap was very reliable. In comparison to the limited number of skin flaps available at the time, the introduction of muscle flaps provided a vast range of possibilities for wound reconstruction.

The major benefit of a muscle or myocutaneous flap is the reliable blood supply based on the main source vessel, often measuring 2 to 4 mm in diameter. Some early reports suggested that this conferred an improved ability to clear infections in the wound. Muscle flaps can be transferred as pedicled local or regional flaps or distantly as free tissue transfers. In the initial reports, the muscle flaps were generally used as pedicled flaps. Wounds with a significant dead space, in particular, are ideally suited for muscle or myocutaneous flaps.

**Muscle Flap Classification**
Muscles are supplied by a dominant, minor, or segmental vascular pedicle (or pedicles), or any combination thereof. Muscles are typically classified based on their vascular supply, as described by the Mathes and Nahai classification, Types I through V.85 This classification was originally published by Mathes and Nahai in 1981 in a landmark study of the vascular anatomy of muscles. The pattern of vascular supply to each muscle guides how the muscle flap may be safely elevated and transferred. The patterns are based on several variables in the anatomic configuration of vascular pedicles entering the muscle: (1) the regional source of the arterial pedicle (or pedicles) entering the muscle, (2) the size of the artery supplying the muscle, (3) the number of pedicles, (4) the location in relation to the origin and insertion, and (5) the patterns of the internal muscle vessels.
Chapter 2 • Vascular Basis of Flaps and Flap Classification

Fig. 2-25 Patterns of vascular anatomy: type I, one vascular pedicle; type II, dominant pedicle(s) and minor pedicle(s); type III, two dominant pedicles; type IV, segmental vascular pedicles; type V, one dominant pedicle and secondary segmental pedicles.

**Table: Examples of Useful Muscle Flaps**

<table>
<thead>
<tr>
<th>Flap</th>
<th>Vascular Supply</th>
<th>Pattern of Circulation</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrocnemius</td>
<td>Medial or lateral sural artery and venae comitantes</td>
<td>Type I</td>
<td>8 x 20</td>
</tr>
<tr>
<td>Gracilis</td>
<td><strong>Dominant:</strong> Medial circumflex femoral artery and venae comitantes <strong>Minor:</strong> Superficial femoral artery</td>
<td>Type II</td>
<td>8 x 15</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td><strong>Dominant:</strong> Superior gluteal artery <strong>Dominant:</strong> Inferior gluteal artery</td>
<td>Type III</td>
<td>24 x 24</td>
</tr>
<tr>
<td>Rectus abdominis</td>
<td><strong>Dominant:</strong> Superior deep epigastric artery and venae comitantes <strong>Dominant:</strong> Inferior deep epigastric artery and venae comitantes</td>
<td>Type III</td>
<td>25 x 6</td>
</tr>
<tr>
<td>Serratus</td>
<td><strong>Dominant:</strong> Lateral thoracic artery and venae comitantes <strong>Dominant:</strong> Branch of thoracodorsal artery and venae comitantes</td>
<td>Type III</td>
<td>15 x 20</td>
</tr>
<tr>
<td>Sartorius</td>
<td>Segmental: Six or seven branches of superficial femoral artery and vein</td>
<td>Type IV</td>
<td>5 x 40</td>
</tr>
<tr>
<td>Extensor digitorum</td>
<td>Segmental: Eight to ten arterial muscular branches and venae comitantes from anterior tibial artery</td>
<td>Type IV</td>
<td>4 x 35</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td><strong>Dominant:</strong> Thoracodorsal artery and venae comitantes <strong>Segmental:</strong> Posterior intercostal arteries and veins (lateral row perforators) <strong>Segmental:</strong> Lumbar artery and vein (medial row perforators)</td>
<td>Type V</td>
<td>25 x 35</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td><strong>Dominant:</strong> Thoracoacromial artery and vein <strong>Segmental:</strong> First through sixth internal mammary artery perforators <strong>Segmental:</strong> Fifth through seventh rib intercostal perforators <strong>Minor:</strong> Pectoral branch of lateral thoracic artery</td>
<td>Type V</td>
<td>15 x 23</td>
</tr>
</tbody>
</table>
Mathes-Nahai Classification

**Type I: One Vascular Pedicle**
Type I muscles have a single vascular pedicle that enters the muscle.

Examples: Gastrocnemius, rectus femoris, tensor fascia lata, abductor digiti minimi, abductor pollicis brevis, anconeus, first dorsal interosseus, genioglossus, hyoglossus, vastus lateralis.

**Type II: Dominant Vascular Pedicles and Minor Pedicles**
Type II muscles have one or more large vascular pedicles that enter the muscle near the origin, or less commonly, at the insertion, and one or more small pedicles that enter the muscle belly. The minor pedicles supplying type II muscles are not able to support the muscle, after ligation of the dominant pedicle. This pattern is the most common.

Examples: biceps femoris, abductor digiti minimi, brachioradialis, coracobrachialis, flexor carpi ulnaris, flexor digitorum brevis, gracilis, peroneus brevis, peroneus longus, platysma, rectus femoris, soleus, sternocleidomastoid, trapezius, triceps, vastus lateralis.

Fig. 2-26 The medial and lateral gastrocnemius muscles are each supplied by a single vascular pedicle from the popliteal artery.

Fig. 2-26 The vastus lateral is mainly supplied by the lateral circumflex femoral artery (1, transverse branch and 2, descending branch) and by perforating arteries from the profunda femoral artery as minor pedicles (3).
**Type III: Two Dominant Pedicles**
Type III muscles have two large vascular pedicles that arise from separate regional arteries. The two pedicles fill the intramuscular vasculature equally, and either one could independently support the muscle or myocutaneous flap.

Examples: Gluteus maximus, rectus abdominis, serratus anterior, temporalis, pectoralis minor.

**Type IV: Segmental Vascular Pedicles**
Type IV muscles have multiple pedicles of similar size that enter the muscle throughout its course, from origin to insertion. These segmentally located pedicles equally fill the muscle vasculature.

Examples: Sartorius, extensor digitorum longus, extensor hallucis longus, external oblique, flexor digitorum longus, flexor hallucis longus, tibialis anterior.

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Fig. 2-26 The rectus abdominis is supplied by the superior (A) and inferior (B) epigastric arteries.

Fig. 2-26 The sartorius muscle has a segmental vascular supply from the lateral circumflex femoral artery (A) and the superficial femoral artery (B)
**Type V: One Dominant Vascular Pedicle and Secondary Segmental Vascular Pedicles**

Type V muscles have a single large pedicle that enters the muscle near its insertion and multiple segmental pedicles that enter the muscle close to its origin. Both systems provide significant vascular supply to the muscle, and a flap could be elevated based on either system.

Examples: Pectoralis major, internal oblique, latissimus dorsi.

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**Donor Site Morbidity**

The use of a muscle flap results in the loss of function of the muscle used. Although this is usually not a significant loss of function, there will be varying degrees of morbidity and functional loss, based on the selected donor muscle and the patient’s occupation and lifestyle. The latissimus flap, for example, is a workhorse flap for reconstruction of defects to the trunk, chest, back, and head and neck. It is generally accepted that there are minimal clinical implications in sacrificing this muscle, unless the patient is an avid climber or swimmer, has an occupation that involves climbing ladders, or is a paraplegic and self-transfers with his or her arms.

**Free Microvascular Tissue Transfer**

The introduction of free autologous tissue transfer using microsurgical vessel anastomoses marked a momentous innovation, which opened a new landscape of possibilities for the reconstructive surgeon. As noted earlier, in 1973 Taylor et al. published the first clinical application of a free composite tissue transfer with reanastomosis at a distant site and thereby coined the term *free flap*. This first free flap was a groin flap based on the superficial inferior epigastric vessels used for a large medial ankle defect. The emergence of free flap reconstruction was possible because of the concurrent development of the operating microscope,
microninstruments, and sutures and knowledge of the cutaneous vasculature. It heralded the beginning of an era of greatly improved ability to transfer tissues throughout the body.

Free flaps have become a versatile and instrumental component of the reconstructive surgeon’s armamentarium. The requirements for free flap transfer include an adequate and reliable vascular pedicle that supplies a dependable segment of tissue. Ideally, the selected donor site should incur minimal morbidity and leave an inconspicuous defect. A multitude of free flap variations have continued to evolve over the years, including microvascular transfers of skin, muscle, bone, tendon, nerve, functional muscle transfers, sensate skin free flaps, and a wide variety of combinations of the tissues (Siamese, conjoint, sequential).

PERFORATOR FLAPS

A perforator flap can be strictly defined as a tissue transfer nourished by a myocutaneous perforator. Practically, however, the perforator flap technique has expanded to any perforator to the skin, including both myocutaneous and septocutaneous vessels. Myocutaneous and fasciocutaneous free flaps are the predecessors of perforator flaps. There was great enthusiasm for myocutaneous flaps during the 1970s and 1980s, and free flaps were being more widely used for wound reconstruction. An abundance of flaps were described, and our understanding of vascular anatomy continued to expand. It was proposed that any muscle with a blood supply that could be isolated as a pedicle could be raised as a flap. The principle advantage of perforator flaps initially was the large and reliable pedicle size of a muscle flap without the disadvantage of the sacrifice of muscle function. It is possible to base perforator flaps on many of the body’s approximately 400 cutaneous perforators. As experience with perforator flaps grew, it became clear that perforator flap technique was being used to develop many new and useful flaps.

<table>
<thead>
<tr>
<th>Flap</th>
<th>Vascular Supply</th>
<th>Pattern of Circulation</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIEP</td>
<td>Deep inferior epigastric artery perforators</td>
<td>Indirect</td>
<td>Zones I to III (sometimes IV) of lower abdomen</td>
</tr>
<tr>
<td>SGAP</td>
<td>Superior gluteal artery perforator</td>
<td>Indirect</td>
<td>10 x 26</td>
</tr>
<tr>
<td>IGAP</td>
<td>Inferior gluteal artery perforator</td>
<td>Indirect</td>
<td>10 x 26</td>
</tr>
<tr>
<td>LCFAP (anterolateral thigh)</td>
<td>Lateral circumflex femoral artery perforator</td>
<td>Direct</td>
<td>9 x 22</td>
</tr>
<tr>
<td>TDAP</td>
<td>Thoracodorsal artery perforator</td>
<td>Indirect</td>
<td>14 x 25</td>
</tr>
<tr>
<td>Lateral arm flap</td>
<td>Posterior radial collateral artery</td>
<td>Direct</td>
<td>8 x 12</td>
</tr>
<tr>
<td>Medial groin</td>
<td>Medial circumflex femoral artery perforator</td>
<td>Indirect</td>
<td>8 x 15</td>
</tr>
</tbody>
</table>
The early pioneers of perforator flaps demonstrated that with meticulous dissection of the vascular pedicle through the intramuscular course, the inclusion of a portion of muscle to act as a carrier for integument was unnecessary. In 1988 Koshima et al described a medial thigh perforator flap, and Kroll and Rosenfield described several cases of successful midline back defects reconstructed with laterally based rotation myocutaneous flaps.

The pedicled TRAM and subsequently the free TRAM flap were the gold standards of autologous breast reconstruction in the 1980s and 1990s. However, postoperative abdominal muscle weakness, contour abnormalities, and possible abdominal hernias were acknowledged as risks of rectus abdominis muscle and fascia harvest. Koshima and Soeda successfully performed two completely muscle-sparing DIEA skin flaps for wound reconstructions in 1989. The clinical application of DIEA perforator flaps was further described and refined by others in the years that followed, for breast reconstruction as well as other defects. Multiple studies have investigated the differences in donor site morbidity after a TRAM flap breast reconstruction compared to a DIEP flap. There is good evidence that the DIEP flap donor site is superior to a pedicled TRAM flap donor site and there is some evidence that abdominal donor site function after DIEP flap harvest is superior to muscle sparing TRAM flap; however, this has not been definitively documented.

Myocutaneous perforator flaps are generally based on the territory’s dominant blood vessel. Following flap dissection, the underlying muscle will survive on the remnant vascular supply from the source artery of the angiosome and/or collateral vessels. Interestingly, the underlying muscle of a perforator flap can sometimes be used if necessary to salvage a compromised pedicled perforator flap. Hallock reported a failed pedicled medial sural artery perforator flap salvaged with a pedicled medial gastrocnemius flap.

Vascular Basis of Perforator Flaps
The clinical use of perforator flaps requires a thorough understanding of the cutaneous vasculature and the cutaneous perforators in the region of interest. There are approximately 400 cutaneous perforators to the skin that can be divided into 61 vascular territories. Each cutaneous perforator could potentially be used for a local, regional, or free perforator flap transfer. Knowledge of the patterns of perforator architecture will allow a reconstructive surgeon the opportunity to customize the reconstruction using the optimal skin type in an expendable donor site region. However, the individual perforators to the skin are highly variable in diameter and location; therefore a method for identifying the perforator preoperatively is advantageous. Initially a handheld Doppler was used to identify the perforators preoperatively; however, this method has some associated inaccuracy and has been largely supplanted by duplex or color Doppler, CT angiography MRA, and ICG laser angiography.

Advantages and Disadvantages of Perforator Flaps
Myocutaneous perforator flaps offer several advantages over a traditional myocutaneous flap. Perforators take advantage of the robust blood vessels that supply the underlying muscle, without the need to sacrifice the muscle. Perforator flaps incur no functional deficit, have less donor site morbidity, improved postoperative recovery, and allow for greater versatility in flap design. Without the need to incorporate the muscle, a perforator flap may be tailored to fit the recipient site precisely. However, perforator flaps require careful, delicate dissection of the vascular pedicle, which may translate to a longer operative time.
Because of the variability of the cutaneous vascular anatomy, it may not be technically possible to perform the planned perforator flap of a specific territory. A planned DIEP flap can be converted to a muscle-sparing free TRAM flap if the patient's anatomy is not favorable. If there are small perforators or if the perforators are damaged, alternative flaps, including a muscle-sparing free TRAM or SIEA flap, can be used.110

Fig. 2-27 The vascular territories of the body that correspond to sources arteries providing myocutaneous or septocutaneous perforators to the skin.
Local Perforator Flaps

A local perforator flap can be defined as a cutaneous flap based on a single perforator that is raised and transferred locally. Local perforator flaps have been reported by Taylor et al using a Doppler probe to assist in detection of the position of the perforator. Other radiographic techniques such as color Doppler and CT angiography give a more detailed view of the underlying perforator anatomy. The surgical technique involves identification of the perforator and dissection of the perforator below the fascial level to completely free the perforator for transfer of the flap. Teo described the propeller flap, which is an elegant local perforator used for reconstruction of defects throughout the body. Local perforator flaps represent a significant improvement over conventional local random or geometric flaps, since the inclusion of a perforator in the base of the flap provides a much more reliable vascularity to the flap.

Fig. 2-28  Design of a local perforator flap. A, A local perforator flap is planned on the upper abdomen in the territory of the deep inferior epigastric artery, extending into the territory of the lateral intercostal artery. B, An angiogram of the human skin of the abdomen showing a number of vascular territories including the deep inferior epigastric artery (DIEA), lateral intercostal artery perforators (LICA), superior epigastric artery (SEA), superficial circumflex iliac artery (SCIA), and superficial inferior epigastric artery (SIEA).
The quest to reliably transfer tissues throughout the body has stimulated surgeons to re-examine the vasculature of the human body. The byproduct of the quest has been the description of hundreds of different flaps. The evolution continues as surgeons gradually determine optimal approaches to specific clinical challenges. However, major questions remain, such as “How much tissue can be based on specific sized pedicle vessels?” and “How can we increase the diameter of flap vessels?” Clear, unbiased descriptions of results and good communication about the vascular basis of different flaps will assist in determining the best flap for the job. This evolution of flap choice should and will continue to improve results in reconstructive surgery.

Bibliography With Key Annotations


Island “perforator flaps” have become state of the art for free skin flap transfer. Recent articles by Saint-Cyr et al and Razen et al have focused on the anatomic and the clinical territories of individual cutaneous perforating arteries in flap planning, and it is timely to compare this work with our angiosome concept. The angiosome concept, first published in 1987, was reviewed and correlated with key experimental and clinical work by the authors, published subsequently at

CONCLUSION

The quest to reliably transfer tissues throughout the body has stimulated surgeons to re-examine the vasculature of the human body. The byproduct of the quest has been the description of hundreds of different flaps. The evolution continues as surgeons gradually determine optimal approaches to specific clinical challenges. However, major questions remain, such as “How much tissue can be based on specific sized pedicle vessels?” and “How can we increase the diameter of flap vessels?” Clear, unbiased descriptions of results and good communication about the vascular basis of different flaps will assist in determining the best flap for the job. This evolution of flap choice should and will continue to improve results in reconstructive surgery.
different times in different journals. In addition, new data are introduced to define these anatomic and clinical territories of the cutaneous perforators and to aid in the planning of safe skin flaps for local and free flap transfer. The anatomic territory of a cutaneous perforator was defined in the pig, dog, guinea pig, and rabbit by a line drawn through its perimeter of anastomotic vessels that link it with adjacent perforators in all directions. The safe clinical territory of that perforator—seen not only in the same range of animals but also in the human using either the Doppler probe or computed tomography angiography to locate the vessels—was found reliably to extend to include the anatomic territory of the next adjacent cutaneous perforator, situated radially in any direction. The data provided by Saint-Cyr et al and Rozen et al, coupled with the authors’ own original work on the vascular territories of the body and their subsequent studies, reinforce the angiosome concept and provide the basis for the design of safe flaps.


The recent enthusiasm for perforator flaps underlines the need for a detailed understanding of the cutaneous vasculature. The principle determinant of success in perforator flap surgery is the inclusion of an adequately sized cutaneous perforator in the flap. Therefore the size, distribution, and variability of cutaneous perforators of the human body are crucial to the design and execution of successful perforator flap surgery. Based on numerous anatomic studies, the authors found that the main source arteries supplying the skin are fairly constant, but the individual cutaneous perforators are quite variable. Knowledge of the overall architecture of the vasculature and an awareness of the variability, combined with a flexible operative plan, will enable the perforator flap surgeon to take advantage of the most appropriate perforators to execute a successful operative plan.


The blood supply to the skin and underlying tissues was investigated by ink injection studies, dissection, perforator mapping and radiographic analysis of fresh cadavers and isolated limbs. The results were correlated with previous regional studies done in this department. The blood supply is shown to be a continuous three-dimensional network of vessels not only in the skin but in all tissue layers. The anatomic territory of a source artery in the skin and deep tissues was found to correspond in most cases, giving rise to the angiosome concept. Arteries closely follow the connective tissue framework of the body. The primary supply to the skin is by direct cutaneous arteries that vary in caliber, length, and density in different regions. This primary supply is reinforced by numerous small indirect vessels, which are “spent” terminal branches of arteries supplying the deep tissues. An average of 374 major perforators was plotted in each subject, revealing that there are still many more potential skin flaps. The arterial roadmap of the body provides the basis for the logical planning of incisions and flaps. The angiosomes defined the tissues available for composite transfer.


The venous architecture of the integument and the underlying deep tissues was studied in six total-body human fresh cadavers and a series of isolated regional studies of the limbs and torso. A radiopaque lead oxide mixture was injected, and the integument and deep tissues were dissected
and radiographed. The sites of the venous perforators were plotted and traced to their underlying parent veins that accompany the source (segmental) arteries. A series of cross-sectional studies were made in one subject to illustrate the course of the perforators between the integument and the deep tissues. The veins were dissected under magnification to identify the site and orientation of the valves. Results revealed a large number of valveless (oscillating) veins within the integument and deep tissues that link adjacent valved venous territories and allow equilibration of flow and pressure throughout the tissue. Where choke arteries define the arterial territories, they are matched by boundaries of oscillating veins in the venous studies. The venous architecture is a continuous network of arcades that follow the connective-tissue framework of the body. The veins converge from mobile to fixed areas, and they “hitchhike” with nerves. The venous drainage mirrors the arterial supply in the deep tissues and in most areas of the integument in the head, neck, and torso. In the limbs, the stellate pattern of the venous perforators is modified by longitudinal channels in the subdermal network. However, when an island flap is raised, these longitudinal channels are disconnected, and once again the arterial and venous patterns match. The venous studies add strength to the angiosome concept. Where source arteries supply a composite block of tissue, we have demonstrated radiologically and by microdissection that the branches of these arteries are accompanied by veins that drain in the opposite direction and return to the same locus. Hence each angiosome consists of matching arteriosomes and venosomes. The clinical implications of these results were discussed with particular reference to the design of flaps, the delay phenomenon, venous free flaps, the pathogenesis of flap necrosis, the “muscle pump,” varicose veins, and venous ulceration.


In 1987 the results of a series of total-body investigations of the arterial system of the skin and underlying deep tissues were published. This resulted in the angiosome concept. In 1990 a similar series of studies of the venous network was published. In both investigations, it was noted that “vessels hitchhike with nerves.” This anatomic study analyzed these neurovascular relationships in the skin and in the underlying muscles. Seven fresh human cadavers and nine animals were studied over a 2-year period. The entire integument of each and a total of 538 human and 72 animal muscles were removed and analyzed. Either the arterial or the venous system was injected with a radiopaque lead oxide mixture, and the dissected nerves were labeled with fine wires and were segregated later by a subtraction radiography technique. The authors presented the results of these investigations, with special emphasis on the design of long axial skin flaps placed along neurovascular systems and their relationship with the current design of skin flaps. The muscles were classified according to their extrinsic and intrinsic neurovascular supplies and suggestions made as to how they may or may not be subdivided into functional units for local and distant transfer. The cutaneous nerves, as well as the motor nerves of the muscles, were invariably accompanied by a longitudinal system of arteries and veins that often was the dominant supply to the region. Whether the nerves appeared together with the vessels, whether the nerves crossed them at an angle, or whether they approached the vessels from opposite directions, in each case the main trunk of the vessel or some of its branches soon “peeled off” to course parallel to the nerve. This information provides the basis for the design of long skin flaps placed along neurovascular systems. Indeed, it reveals that many of the current “axial” or “fasciocutaneous” skin flaps used in clinical practice are in fact neurovascular flaps.


The Doppler probe was used to identify the dominant cutaneous perforating arteries in a series of 10 patients. The results were compared with our previous total body fresh cadaver anatomic studies and a close correlation was found. The instrument was used in a series of patients to plan the base, the axis and the dimensions of skin flaps for local, distant and free transfer. A dominant perforator was located at the base of the flap, the surrounding skin was scanned to identify the next dominant perforator in each direction and the appropriate axis was chosen by drawing a line between two nominated perforator. Often the flap was based distally or its axis departed from the main course of the supplying vessel. The technique proved to be simple and reliable and in many cases flaps of unusual dimensions and directions were transferred successfully. The instrument provides a useful link between the anatomic dissecting room and the operating theater.


The success of fasciocutaneous flaps is based on the existence of epifascial vascular networks and reliable blood supply. However, there has been no thorough classification of the vascular anatomy of the fascia and skin and there is some confusion in regard to cutaneous vascular nomenclature. The authors divided the vascular systems involved in the cutaneous circulation into four
categories. This permits classification of skin flaps into five types (cutaneous, fasciocutaneous, adipofascial, septocutaneous, and myocutaneous flaps). Fasciocutaneous flaps can be further divided into six types, according to the patterns of the vascular input to the fasciocutaneous plexus. This classification has been demonstrated to be related to clinical effects. Nine new free and island flaps were discussed.


The author observed that the effectiveness of the muscle flap in the management of osteomyelitis is related to two factors: (1) wound debridement is less restricted because of the ability of the muscle flap to provide coverage in one operation, and (2) well-vascularized muscles are applied directly to the bone defect, bringing a new source of antimicrobial defense.


The authors reviewed the cases of 11 patients with chronic osteomyelitis involving the distal tibia and foot who were successfully treated with a combination of debridement and immediate microvascular muscle transplantation. Diagnosis of chronic osteomyelitis was confirmed by demonstration of radiographic and histologic abnormality, along with positive bone culture results. Experience data were presented to support the effectiveness of muscle flap coverage of the infected wound. The authors introduced two useful concepts in muscle transplantation to leg defects: (1) selection of receptor vessels to the leg defect based on arteriographic evaluation of suitable receptor vessels, and (2) use of end-to-side venous anastomosis as well as established techniques of end-to-side arterial anastomosis. A comparison of long-term results notes improved contour of the muscle flap with a skin flap as compared with a myocutaneous flap. All patients in this series demonstrated resolution of chronic bone infection at an average follow-up of 1.8 years.


Experimental studies were undertaken in dogs to determine whether useful island myocutaneous flaps could be based on the gracilis, sartorius, biceps femoris, trapezius, or rectus abdominis muscles. Dissection and injection studies on these muscles were also undertaken in human cadavers to determine the contributions of these muscles to the blood supply of the overlying skin. In most instances it was considerable. The use of island myocutaneous flaps seems promising in many situations. Such transfers can be done in one operation, without delay procedures, and result usually in a better blood supply with the transfer of a thicker amount of tissue. Clinical research on such flaps in patients was to be described in a subsequent paper.


A number of myocutaneous flaps are described for the first time. This article includes a description of 13 myocutaneous flaps. The size of each unit and its vascular basis are described.


A rectus abdominis myocutaneous island flap for breast reconstruction following mastectomy was presented. The vascular anatomy of the abdominal wall was clinically studied in patients undergoing abdominal lipectomy. Cadaver dissections were shown, demonstrating the anatomy, arc of rotation, and design alternatives of the rectus abdominis flap. The surgical technique was demonstrated and representative patients were shown.


The vascular territories of the superior and the deep inferior epigastric arteries were investigated by dye injection, dissection, and barium radiographic studies. By these means it was established that the deep inferior epigastric artery was more significant than the superior epigastric artery in supplying the skin of the anterior abdominal wall. Segmental branches of the deep epigastric system pass upward and outward into the neurovascular plane of the lateral abdominal wall, where they anastomose with the terminal branches of the lower six intercostal arteries and the ascending branch of the deep circumflex iliac artery. The anastomoses consist of multiple narrow “choke” vessels. Similar connections are seen between the superior and the deep inferior epigastric arteries within the rectus abdominis muscle well above the level of the umbilicus. Many perforating arteries emerge through the anterior rectus sheath, but the highest concentration of major perforators is in the paraumbilical area. These vessels are terminal branches of the deep inferior epigastric artery. They feed into a subcutaneous vascular network that radiates from the umbilicus like the spokes of a wheel. Once again, choke connections exist with adjacent territories: inferiorty with the superficial inferior epigastric artery, inferolaterally with the superficial circumflex iliac artery, and superiorly with the superficial superior epigastric artery. The dominant connections, however, are superolaterally with the lateral cutaneous branches of the intercostal arteries. For breast reconstruction, it would appear that prior ligation of the deep inferior epigastric artery would be of advantage when elevating the lower abdominal skin on a superiorly based rectus abdominis myocutaneous flap. The vascularity of this flap would be further increased by positioning some part of the skin paddle over the dense pack of large paraumbilical perforators. Based on these anatomic studies, the relative merits of the superior and deep inferior epigastric arteries with respect to local and distant tissue transfer using various elements of the abdominal wall are discussed in detail.


The previously described “perfusion zones” of the abdominal wall vasculature are based on filling of the deep inferior epigastric artery (DIEA) and all its branches simultaneously. With the advent of the DIEA perforator flap, only a single or several perforators are included in the supply to the flap. As such, a new model for abdominal wall perfusion has become necessary. The authors explored the concept of a “perforator angiosome.” They undertook a clinical and cadaveric study of 155 abdominal walls. This comprised the use of 10 whole, unembalmed cadaveric abdominal walls for angiographic studies and 145 abdominal wall CT angiograms in
patients undergoing preoperative imaging of the abdominal wall vasculature. The evaluation of the subcutaneous branching pattern and zone of perfusion of individual DIEA perforators was explored, particularly exploring differences between medial and lateral row perforators. Fundamental differences exist between medial row and lateral row perforators, with medial row perforators larger (1.3 mm versus 1 mm) and more likely to ramify in the subcutaneous fat toward the contralateral hemiabdomen (98% of cases versus 2% of cases). A model for the perfusion of the abdominal wall based on a single perforator is presented. The “perforator angiosome” is dependent on perforator location, and can be mapped individually with the use of preoperative imaging.


Experimental skin flaps have been used by researchers for almost a century to investigate many of the perplexing questions in plastic and reconstructive surgery, yet the underlying vascular anatomy of these flaps is addressed infrequently. The purpose of this study was to predict the survival of experimental skin flaps before their elevation in guinea pigs and rabbits, planned on a knowledge of the underlying vascular anatomy. On the basis of the authors’ previous anatomic studies, 17 guinea pigs and 15 rabbits were used in separate experiments. In experiment 1, two parallel flank flaps of identical dimensions were compared on one side of each guinea pig. The dorsal flap encompassed the vascular territories of multiple perforators, while the ventral flap embraced two perforators (two-territory flap). Viability was assessed on days 3 and 7 by inspection and fluorescein dye injection. All ventral flaps survived to a greater extent than the dorsal flaps. Whole-body fresh cadaver lead oxide injections were performed to provide cutaneous angiograms. It was found in each flap that the area of skin viability corresponded to the capture of one to two adjacent vascular territories on the artery at its base. In the second experiment, a multiple-territory osteocutaneous flap was designed on one side of the torso of the rabbit using the Doppler probe. It was based on the thoracodorsal artery and embraced the skin and a 1 by 2 cm segment of iliac crest bone in the adjacent deep circumflex iliac artery angiosome. Using the same criteria as in experiment 1, the authors found that one to two adjacent viable skin territories were captured on the thoracodorsal artery. In addition, viability of the iliac bone was confirmed in every case by angiography, fluorochrome labeling, and india ink injection studies indicating the capture of deep structures of the deep circumflex iliac artery angiosome. This study reinforces the angiosome concept and indicates that one adjacent vascular territory may be captured reliably in experimental guinea pig and rabbit skin flaps. The authors described a reliable osteocutaneous flap model in the rabbit.


A number of experiments were conducted to study the anatomic changes in a flap following a surgical delay using the Doppler probe to add precision to the technique. After scanning the integument of a series of anesthetized animals with the probe, each was sacrificed; a total-body arterial injection was performed with a lead oxide mixture, the integument and deep tissues were radiographed separately, and the results were correlated and compared with our previous human studies. The dog was selected from the range of animals examined, and the arterial networks of a number of skin and muscle flaps were studied with and without a surgical delay. The study included the use of a tissue expander. Results revealed that an adjacent cutaneous perforator could be captured with safety on the artery at the base of an undelayed flap; that the survival length of that flap was related to the distance between perforators; that the necrosis line
of the flap usually appeared in the zone of choke vessels connecting adjacent territories; that a surgical delay results in a dilatation of existing vessels with maximal effect in the zone of choke arteries; that the most effective delay was obtained by elevating the flap in stages from the base, leaving detachment of the tip until last; that tissue expansion is a form of surgical delay, with particular emphasis on vessel hypertrophy; and that similar changes occur when a muscle is delayed. The clinical applications of this investigation were presented in part II of this anatomic review of the delay phenomenon.


The authors previously showed that when a flap is delayed, the maximal anatomic effect on the arterial side of the circulation is focused at the level of the smaller-caliber choke vessels that link adjacent vascular territories. These anastomotic vessels were noted to increase in size to the dimension of true anastomoses. However, we did not define when this occurred. The present experiment therefore was designed to elucidate the chronologic sequence of events that occur in the “choke” vessels using a rabbit flank skin flap as the experimental model. A long two-territory osteocutaneous flank flap was designed on one side of each rabbit (n = 30), with the opposite unoperated side serving as a control. The flap was elevated and sutured back in place. At various times postoperatively, namely, 1 (n = 2), 2 (n = 2), 3 (n = 2), 4 (n = 2), 6 (n = 2), 8 (n = 2), 12 (n = 2), 24 (n = 2), 48 (n = 2), and 72 (n = 2) hours and 7 days (n = 10), the animals were sacrificed, and total-body arteriograms were obtained using a lead oxide mixture. The density and size of the choke arteries between the territories in the flap and their counterparts on the control side were assessed by histologic analysis (n = 3). The authors observed a sequential dilation of choke vessels during the delay period. In particular, the authors found that the vessels increased rapidly in size between the 48- and 72-hour studies.


The authors described five patterns of muscle circulation, based on studies of the vascular anatomy of muscle. Clinical and experimental correlation of this classification was determined by the predictive value of the vascular pattern of each muscle currently useful in reconstructive surgery in regard to the following parameters: arc of rotation, skin territory, distally based flaps, microvascular composite tissue transplantation, and design of muscle-delay experimental models. This classification was designed to assist the surgeon both in choice and design of the muscle and myocutaneous flap for its use in reconstructive surgery.


The unique niche for compound flaps is their potential role for the repair of massive defects that demands the simultaneous restoration of multiple missing tissue types. These complex flaps can be sorted into two major classes; the author described their subtypes on the basis of their means
of vascularization: (1) solitary vascularization, the composite flap: “multiple tissue components with a single vascular supply and dependent parts” and (2) combined flaps: (a) Siamese flaps: “multiple flap territories, dependent due to some common physical junction, yet each retaining their independent vascular supply”; (b) conjoint flaps: “multiple independent flaps, each with an independent vascular supply, but linked by a common indigenous source vessel”; and (c) sequential flaps: “multiple independent flaps, each with an independent vascular supply, and artificially linked by a microanastomosis.” Many technical modifications that have improved or will improve the reliability of these flaps should not be confused as distinct flap types, but rather acknowledged as variations that can be more conveniently classified for the purposes of improved communication and research by using this basic schema as a guideline.


The authors reviewed the literature regarding perforator flaps. Myocutaneous perforator flaps have evolved from myocutaneous flaps and offer several distinct advantages. By sparing muscle tissue, thus reducing donor site morbidity and functional loss, perforator flaps are indicated for a number of clinical problems. The versatility of the perforator flap makes it ideal for the reconstruction of three-dimensional defects such as breast reconstruction or as a thin flap for resurfacing shallow wounds when bulk is considered a disadvantage. The authors reviewed the historical development of the perforator flap and discuss the advantages and disadvantages of perforator flaps compared with free and pedicled myocutaneous flaps. The nomenclature traditionally used for perforator flaps is confusing and lacks a standardized anatomic basis. The authors presented a method to describe all perforator flaps according to their artery of origin.


A new type of flap was described based on unnamed perforators located near the midline of the lower back region. Such flaps combine the superior blood supply of the myocutaneous flap with the lack of donor-site morbidity of a skin flap. Five clinical cases were presented, showing how such perforators can augment skin flaps or create custom-designed island flaps. The dissection of the flap was described, and further possibilities for its use were suggested.


The anteromedial thigh flap first described by Song is a septocutaneous artery flap based on the septocutaneous perforator originating from the lateral circumflex femoral vessels and long saphenous vein. The authors reported the use of this flap for three patients who required soft tissue coverage. The most important advantage of this flap is that it can be used not only as a skin flap but also as a vascularized fascia graft and fasciocutaneous free flap for the full-thickness defect of the abdominal wall and cranial region.


The ideal material for reconstruction of a breast is fat and skin. Most current methods of autologous reconstruction use myocutaneous flaps. The authors investigated the feasibility of transfer of skin and fat from the lower abdomen without muscle sacrifice. The flap is based on one, two, or three perforators of the deep inferior epigastric vessels. Their study demonstrated both experimentally and clinically this original technique for breast reconstruction. Fifteen breasts were successfully reconstructed with this technique. This technique has all of the advantages of the free TRAM flap with a decreased possibility of ventral hernia or muscle weakness.

The TRAM flap has been the gold standard for breast reconstruction until recently. Not only autologous but also immediate reconstructions are now preferred to offer the patient a natural and cosmetically acceptable result. This study summarized the prospectively gathered data of 100 free DIEP flaps used for breast reconstruction in 87 patients. Primary reconstructions were done in 35% of the patients. Well-known risk factors for free flap breast reconstruction were present: smokers 23%, obesity 25%, abdominal scarring 28% and previous radiotherapy 45%. Free DIEP flaps vascularized by a single (52%) perforator, two (39%) perforators, or three (9%) perforators were preferentially anastomosed to the internal mammary vessels at the level of the third costochondral junction. Of 74 unilateral DIEP flaps, 41 (55%) flaps were well vascularized in zone IV. Two flaps necrosed totally. Partial flap loss and fat necrosis occurred in 7% and 6% of all flaps, respectively. One patient presented with a unilateral abdominal bulge. Mean operating time was 6 hours 12 minutes for unilateral reconstruction and mean hospital stay was 7.9 days. These data indicate that the free DIEP flap is a reliable and safe technique for autologous breast reconstruction. This flap offers the patient the same advantages as the TRAM flap and avoids the most important disadvantages of the myocutaneous flap by preserving the continuity of the rectus muscle. The donor site morbidity is reduced, a sensate reinnervation is possible, postoperative pain is less, recovery is quicker and hospital stay is reduced. The more complex nature of this type of surgery, leading to increased operating time, is balanced by the permanent and gratifying results achieved.


Besides the enormous advantages of reconstructing an amputated breast by means of a conventional TRAM flap, the main disadvantage remains the elevation of small (free TRAM) or larger (pedicled TRAM) parts of the rectus abdominis muscle. To overcome this disadvantage, the free deep inferior epigastric perforator (DIEP) skin flap has been used for breast mound reconstruction with excellent clinical results. After achieving favorable results with eight unilateral DIEP flaps, the authors were challenged by an abdomen with a midline laparotomy scar. By dissecting a bilateral DIEP flap and making adjacent anastomoses to the internal mammary artery, they were able to achieve sufficient flap mobility for easy free flap positioning and breast shaping. Intraoperative segmental nerve stimulation, postoperative functional abdominal wall tests, and CT scan examination showed normal abdominal muscle activity. On the basis of a case report, the technical considerations and advantages of anastomosing the bipedicled DIEP flap to the internal mammary artery were discussed.


The propeller flap, based on a single vascular pedicle supplying a fasciocutaneous island of skin, is a very useful technique for reconstructing soft tissue defects and has wide applications throughout the body. The use of this unique flap is pushing the boundaries of local flap reconstruction and bringing up intriguing questions about our understanding of the vascular basis of fasciocutaneous flaps.
Chapter 3

Guide to Flap Selection

The practice of plastic and reconstructive surgery is as much art as it is science. This explains why different plastic surgeons can successfully solve similar clinical problems with different reconstructive flaps and techniques. Both can be successful. This makes it hard to teach as dogma that one flap or another is the best or should be the standard. It is even harder for the student, whose life is made easier by dogma and repetition. This is especially true in residency, which is effectively an apprenticeship in which the tools of the trade are passed down and one learns the “right” way to solve problems.

To be truly successful in reconstructive surgery, one needs to be flexible, and able to adapt to a given situation—in essence, one needs to be “plastic.” Any worthwhile guide to flap selection will best serve its students by teaching them how to think about the reconstructive problem at hand and to generate a list of possible solutions. Each solution would have its own list of pros and cons. The true art would then be the application of those solutions to a particular patient. And the same clinical problem in a different patient might produce a different list of solutions for that individual.

Although there are unifying principles in plastic surgery, such as “replace like with like” and “mark twice, cut once,” it is best to break down the reconstructive problem into its component parts: patient factors, local factors, and flap factors (see the box on p. 150).

In this way, one can avoid the knee-jerk response of doing the same reconstructive flap in varying clinical situations in dissimilar patients. Time spent breaking down the problem and considering all options preoperatively will pay off by reducing time in the operating room, lowering patient morbidity, and solving the problem at hand.
PATIENT FACTORS
The category of patient factors can be further broken down into the physical and the emotional. As a physician, one’s first and overriding concern is for the patient’s well-being. The event that has led the patient to present to you (such as trauma, cancer, or disease) may in the end limit the choices you have for reconstruction. The physical state of the patient, the multisystem traumatic injury, the metastatic cancer currently being treated, or the medical comorbidities of the patient may severely limit options for long operative procedures or long recoveries. Shorter local or regional procedures may prevail.

The patient’s emotional state and his or her insight into the situation can also weigh heavily on your decision. Is the patient willing to accept scars, and where? What is the desired recovery time? A patient who owns his or her own small business is less able to dedicate the necessary 6 weeks of recovery that a free flap might entail and less able to tolerate a lengthy complication. The patient’s reliability should also factor into the decision-making process. If lengthy follow-up or therapy will be required and the patient is not motivated, the chances of success may be doomed before the incision is made.

LOCAL FACTORS
Location, location, location. Where you are operating will present different reconstructive opportunities. Some anatomic locations, such as the top of the head and the bottom of the feet, offer fewer local and regional options. Previous surgery may affect options for incisions, available tissues, and available recipient vessels. A history of radiation therapy or a plan for postoperative radiation can also alter one’s surgical plans toward more durable flap choices. The concept of “zone of injury” is an important one, not only in trauma cases, but also in all reconstructions. One must strive to be aggressive in the resectioning of involved, infected, poorly vascularized, and poor-quality tissues, and, as much as possible, to use uninjured, well-vascularized, expendable tissues from the region or from distant sites with free tissue transfer. Recipient vessels for such transfers should be clearly out of the involved area to reduce the chances of thrombosis caused by damaged vessels. Finally, the patient’s body habitus can alter one’s choices in flap selection; for example, obesity can change the donor site and has an impact on vascularity, ease of dissection, and ease of flap inset, in addition to an increased potential for donor site morbidity.

FLAP FACTORS
Once the requirements of the reconstruction are clearly delineated, the search for the best solution begins. Each flap has certain characteristics to offer, and these expectations must be confirmed by examining the patient. The concept of “replacing like with like” usually means local tissues. Regional choices are considered first to provide good color and texture match and ease of transfer and to avoid a lengthy microsurgical procedure. The right flap will have the right combination of components needed for the job: muscle, skin, fascia, bone. The best choices for skin supply the needed surface area and allow primary donor site closure. If skin grafting is required for donor site closure, comparison with other flaps is warranted. The character of the transferred skin must also be assessed for texture and color match, durability, and other special features, such as hair and sensibility. If fascia is required, the amount needed and the desire to vascularize the fascia will point to certain
choices. Many flaps can contain muscle, but we also now know that the muscle is a carrier for blood supply and can be left in situ, carrying the skin of the flap via its perforating vessels. One must decide whether the muscle is needed, and if so, how much, and whether a functional transfer of the muscle is required.

All flaps, whether muscle containing or perforator of muscle containing, have some associated donor morbidity, and this again is where the patient’s desires and the art of application come into play. Bone requirements differ with different flaps, and there are always choices. Complex defects that require bone and other tissues may sometimes require more than one flap to solve the problem at hand because of the geometry or sheer size of the defect; this can also be true of defects not requiring bone. Although the natural tendency of surgeons is to solve all problems with one reconstructive flap and the desire of all patients is to have one surgery, the surgeon must be careful not to extend the applicability of a flap or put at risk the reconstruction by trying to do too much with too little. Sometimes a second flap, a delayed inset, or a surgical revision is not a sign of failure, but a good plan.

SURGEON FACTORS
Ultimately, it comes down to you—your skill, your creativity, and your judgment. The good news is that each of these things can improve over time with experience. You will be a better surgeon in the future than you are now. It is true of us all. This book is meant to guide you on that path, to open the door of possibilities and options to you, and to allow you to successfully select flaps to treat patients.

A Guide to Flap Selection by Area
This chapter is organized by anatomic area and is a good starting place in the initial planning process. The anatomic illustrations and accompanying boxes will show you which flaps are available locally, which are the workhorse flaps for that area, and which free flaps are commonly used. If microsurgery is being considered, the most commonly used recipient vessels are listed. Finally, each area of the body has its own special considerations or traps, and a list of suggestions for that area of the body is included. Each flap and each recipient vessel choice is labeled with the page number where the detailed description and dissection guide can be found. Good luck, and much success with your case!
Scalp Reconstruction Options

1. Alopecia may occur with skin grafts and scars.
2. Tissue expansion may be useful.
3. Superficial temporal vessels are larger with proximal dissection beyond the deep temporal branch.
4. Recipient vessels may require an A-V loop to the neck.

Scalp flap

Trapezius flap

Free muscle/skin
### Flap Choice

Flaps are listed in order of popularity.

1. **Scalp** (p. 192)
2. Temporoparietal fascia (TPFF) (p. 262)
3. Trapezius (p. 694)
4. **Omental** (p. 1324)
5. **Latissimus dorsi** (p. 726)
6. **Anterolateral thigh (ALT)** (p. 1350)
7. **Rectus abdominis** (p. 1136)
8. **Free muscle/skin**

### Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Occipital
4. External jugular vein
5. Internal jugular vein

### Things to Consider When Reconstructing the Scalp

1. Alopecia may occur with skin grafts and scars.
2. Tissue expansion may be useful.
3. Superficial temporal vessels are larger with proximal dissection beyond the deep temporal branch.
4. Recipient vessels may require an A-V loop to the neck.

**Red type denotes a workhorse flap.**

**Italic type denotes a free flap.**
Nose Reconstruction Options

Flap Choice

1. Paramedian forehead (p. 170)
2. Nasolabial (p. 232)
3. Radial forearm (p. 842)
4. Scalp (Washio) (p. 192)

Recipient Vessels

Implies artery and vein unless otherwise noted.

1. Facial/angular branch
2. Superficial temporal
3. External jugular vein
4. Internal jugular vein

Things to Consider When Reconstructing the Nose

1. Facial tissues offer the best color match.
2. A free flap may be used for lining and structure, saving the forehead flap for the best resurfacing option.
3. Secondary thinning of flaps is often required to alleviate airway obstruction.
4. Superficial temporal vessels are larger with proximal dissection beyond the deep temporal branch.
5. Recipient vessels may require an A-V loop.

Free Flap

Radial forearm

Nasolabial flap

Paramedian forehead flap

Scalp (Washio) flap
Flap Choice

Flaps are listed in order of popularity.
1. Paramedian forehead (p. 170)
2. Nasolabial (p. 232)
3. Radial forearm (p. 842)
4. Scalp (Washio) (p. 192)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Facial/angular branch
2. Superficial temporal
3. External jugular vein
4. Internal jugular vein

Things to Consider When Reconstructing the Nose

1. Facial tissues offer the best color match.
2. A free flap may be used for lining and structure, saving the forehead flap for the best resurfacing option.
3. Secondary thinning of flaps is often required to alleviate airway obstruction.
4. Superficial temporal vessels are larger with proximal dissection beyond the deep temporal branch.
5. Recipient vessels may require an A-V loop.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Ear Reconstruction Options

Free Flaps

Recipient Vessels

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Occipital
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Ear

1. Thin flaps are best.
2. The TPFF with skin grafting is useful.
3. Deep temporal fascia should be avoided for best coverage of the construct and contour of the ear.
4. If TPFF is unavailable because of trauma or cancer, a TPFF may be considered as a free flap from the contralateral side.
5. Tissue expansion can be advantageous.

Temporoparietal fascia flap (TPFF)
**Chapter 3  Guide to Flap Selection  •  Ear**

### Flap Choice

Flaps are listed in order of popularity.
1. **Temporoparietal fascia (TPFF)** (p. 262)
2. **Temporoparietal fascia (TPFF)** (p. 270)
3. **Free fascia**

### Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Occipital
7. External jugular vein
8. Internal jugular vein

### Things to Consider When Reconstructing the Ear

1. Thin flaps are best.
2. The TPFF with skin grafting is useful.
3. Deep temporal fascia should be avoided for best coverage of the construct and contour of the ear.
4. If TPFF is unavailable because of trauma or cancer, a TPFF may be considered as a free flap from the contralateral side.
5. Tissue expansion can be advantageous.

**Red type denotes a workhorse flap.**

**Italic type denotes a free flap.**
Tongue Reconstruction Options

Flap Choice
Flaps are listed in order of popularity.

1. Tongue (p. 368)
2. Radial forearm (p. 842)
3. Vertical rectus abdominis myocutaneous (VRAM) (p. 1136)
4. Anterolateral thigh (ALT) (p. 1350)
5. Pectoralis major (p. 518)
6. Deltopectoral flap
7. Supraclavicular flap
8. Ulnar forearm
9. Free muscle/skin

Recipient Vessels
Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Tongue

1. Maintaining mobility is important for swallowing and speech.
2. Innervated tissue should be used when possible (to the lingual nerve).
3. Bulk is important after a total glossectomy (ALT, VRAM).
Flap Choice

Flaps are listed in order of popularity.

1. **Tongue** (p. 368)
2. **Radial forearm** (p. 842)
3. **Vertical rectus abdominis myocutaneous (VRAM)** (p. 1136)
4. **Anterolateral thigh (ALT)** (p. 1350)
5. Pectoralis major (p. 518)
6. Deltoperiotic (p. 432)
7. Supraclavicular (p. 546)
8. **Ulnar forearm** (p. 894)
9. **Free muscle/skin**

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Tongue

1. Maintaining mobility is important for swallowing and speech.
2. Innervated tissue should be used when possible (to the lingual nerve).
3. Bulk is important after a total glossectomy (ALT, VRAM).

Red type denotes a workhorse flap.

*Italic type denotes a free flap.*
Lip Reconstruction Options

Free Flaps

Flap Choice

1. Orbicularis oris (p. 334)
2. Facial artery myomucosal (FAMM) (p. 410)
3. Tongue (p. 368)
4. Radial forearm (p. 842)
5. Temporoparietal fascia (mustache) (p. 262)
6. Submental (p. 388)
7. Supraclavicular (p. 546)
8. Deltopectoral (p. 432)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Lip

1. Microstomia must be avoided.
2. Color match is best with local tissues.
3. A mustache can camouflage the lip deformity after reconstruction in men (TPFF or free hair grafts).
4. Tendon or fascial support of the lip is recommended with free flaps (palmaris, plantaris, fascia lata).
5. One should plan for adequate vertical height to anticipate flap shrinkage over time.
6. V-Y advancement of intraoral mucosa can provide vermilion reconstruction, thereby avoiding the need for additional flaps.
7. The surgeon must beware of constricting postoperative dressings or ties that could obstruct vascular pedicles, resulting in flap loss.
**Flap Choice**

Flaps are listed in order of popularity.

1. **Orbicularis oris** (p. 334)
2. **Facial artery myomucosal (FAMM)** (p. 410)
3. **Tongue** (p. 368)
4. **Radial forearm** (p. 842)
5. **Temporoparietal fascia (TPFF) (mustache)** (p. 262)
6. **Submental** (p. 388)
7. **Supraclavicular** (p. 546)
8. **Deltoplectoral** (p. 432)

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

**Things to Consider When Reconstructing the Lip**

1. Microstomia must be avoided.
2. Color match is best with local tissues.
3. A mustache can camouflage the lip deformity after reconstruction in men (TPFF or free hair grafts).
4. Tendon or fascial support of the lip is recommended with free flaps (palmaris, plantaris, fascia lata).
5. One should plan for adequate vertical height to anticipate flap shrinkage over time.
6. V-Y advancement of intraoral mucosa can provide vermilion reconstruction, thereby avoiding the need for additional flaps.
7. The surgeon must beware of constricting postoperative dressings or ties that could obstruct vascular pedicles, resulting in flap loss.

*Red type denotes a workhorse flap.*

*Italic type denotes a free flap.*
Free Flap

Cheek Reconstruction Options

1. Nasolabial (p. 232)
2. Submental (p. 388)
3. Deltopectoral (p. 432)
4. Supraclavicular (p. 546)
5. Temporalis (p. 288)
6. Masseter (p. 316)
7. Free muscle/skin
8. Trapezius (p. 694)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Cheek

1. When possible, the surgeon should respect the aesthetic subunits of the cheek.
2. Local tissues will give the best color and texture match for reconstruction, and one should take advantage of the natural tissue redundancy in the cheek and neck (for example, the Mustarde advancement rotation flap; see Chapter 1).
3. Care should be taken when importing hair-bearing skin into non-hair-bearing areas.
4. It is imperative when reconstructing the cheek that there be no tension on the neighboring lower eyelid, creating ectropion.
5. One should have a low threshold for providing lower lid support.
6. The surgeon must beware of constricting postoperative dressings or ties that could obstruct vascular pedicles, resulting in flap loss.
Chapter 3  Guide to Flap Selection  •  Cheek

**Flap Choice**

Flaps are listed in order of popularity.

1. *Nasolabial* (p. 232)
2. *Submental* (p. 388)
3. *Deltoplectoral* (p. 432)
4. *Supraclavicular* (p. 546)
5. *Temporalis* (p. 288)
6. *Masseter* (p. 316)
7. *Free muscle/skin*
8. *Trapezius* (p. 694)

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. *Superficial temporal*
2. *Facial*
3. *Lingual*
4. *Superior thyroid*
5. *External carotid*
6. *Transverse cervical*
7. *External jugular vein*
8. *Internal jugular vein*

**Things to Consider When Reconstructing the Cheek**

1. When possible, the surgeon should respect the aesthetic subunits of the cheek.
2. Local tissues will give the best color and texture match for reconstruction, and one should take advantage of the natural tissue redundancy in the cheek and neck (for example, the Mustarde advancement rotation flap; see Chapter 1).
3. Care should be taken when importing hair-bearing skin into non-hair-bearing areas.
4. It is imperative when reconstructing the cheek that there be no tension on the neighboring lower eyelid, creating ectropion.
5. One should have a low threshold for providing lower lid support.
6. The surgeon must beware of constricting postoperative dressings or ties that could obstruct vascular pedicles, resulting in flap loss.

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*Red type denotes a workhorse flap.*

*Italic type denotes a free flap.*
**Free Flaps**

**Intraoral Reconstruction Options**

Flap Choice

1. Pectoralis major (p. 518)
2. Radial forearm (p. 842)
3. Tongue (p. 368)
4. Supraclavicular (p. 546)
5. Deltopectoral (p. 432)
6. Submental (p. 388)
7. Facial artery myomucosal (FAMM) (p. 410)
8. Nasolabial (p. 232)
9. Masseter (p. 316)
10. Free muscle/skin

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Intraoral Region

1. A watertight closure should be confirmed to prevent fistula.
2. Tongue mobility should be maintained for swallowing and speech.
3. Hair-bearing skin can be problematic.
4. A feeding tube is placed at the time of flap inset.
5. Complete intraoral reconstruction is not always necessary, because use of an obturator improves cancer follow-up.
6. A clear liquid diet is given until all suture lines are healed.
Chapter 3  Guide to Flap Selection  •  Intraoral  97

Flap Choice

Flaps are listed in order of popularity.
1. **Pectoralis major** (p. 518)
2. **Radial forearm** (p. 842)
3. Tongue (p. 368)
4. Supraclavicular (p. 546)
5. Deltopectoral (p. 432)
6. Submental (p. 388)
7. Facial artery myomucosal (FAMM) (p. 410)
8. Nasolabial (p. 232)
9. Masseter (p. 316)
10. *Free muscle/skin*

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Intraoral Region

1. A watertight closure should be confirmed to prevent fistula.
2. Tongue mobility should be maintained for swallowing and speech.
3. Hair-bearing skin can be problematic.
4. A feeding tube is placed at the time of flap inset.
5. Complete intraoral reconstruction is not always necessary, because use of an obturator improves cancer follow-up.
6. A clear liquid diet is given until all suture lines are healed.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Free Flaps

Skull Base Reconstruction Options

1. Temporalis (p. 288)
2. Temporoparietal fascia (TPFF) (p. 262)
3. Free muscle/skin
4. Omental (p. 1324)

Recipient Vessels

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Skull Base
1. Nonskin, well-vascularized, nonirradiated flaps are best.
2. A lumbar drain helps dural leaks to heal with the flap in place.
3. Free tissue transfer of muscle (rectus abdominis, latissimus dorsi, and ALT) is the most common approach for skull-based reconstruction, because this provides ample tissue fill without the constraints of local pedicle options.
4. Sealing the dural defect should be the top priority in these situations. This is best accomplished with muscle flaps.
5. The surgeon must beware of constricting postoperative dressings or ties that could obstruct vascular pedicles, resulting in flap loss.
Chapter 3  Guide to Flap Selection  •  Skull Base

Flap Choice

Flaps are listed in order of popularity.
1. **Temporalis** (p. 288)
2. **Temporoparietal fascia (TPFF)** (p. 262)
3. **Free muscle/skin**
4. **Omental** (p. 1324)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. External jugular vein
8. Internal jugular vein

Things to Consider When Reconstructing the Skull Base

1. Nonskin, well-vascularized, nonirradiated flaps are best.
2. A lumbar drain helps dural leaks to heal with the flap in place.
3. Free tissue transfer of muscle (rectus abdominis, latissimus dorsi, and ALT) is the most common approach for skull-based reconstruction, because this provides ample tissue fill without the constraints of local pedicle options.
4. Sealing the dural defect should be the top priority in these situations. This is best accomplished with muscle flaps.
5. The surgeon must beware of constricting postoperative dressings or ties that could obstruct vascular pedicles, resulting in flap loss.

**Red type denotes a workhorse flap.**
**Italic type denotes a free flap.**
Free Flaps

Neck Reconstruction Options

Flap Choice

1. Pectoralis major (p. 518)
2. Supraclavicular (p. 546)
3. Deltopectoral (p. 432)
4. Submental (p. 388)
5. Trapezius (p. 694)
6. Latissimus (p. 726)
7. Anterolateral thigh (ALT) (p. 1350)
8. Radial forearm (p. 842)
9. Free muscle/skin
10. Jejunal (p. 1298)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. Thoracoacromial
8. Cephalic vein turnover
9. External jugular vein
10. Internal jugular vein

Things to Consider When Reconstructing the Neck

1. The intraoral space should be separated and sealed from the neck.
2. The neck is a highly mobile area, so one must take into account the full neck motions.
3. Use of a shoulder roll facilitates neck exposure.
4. Microsurgery should be performed with the neck turned toward the opposite side to prevent postoperative tension on the microsurgery site.
5. Postoperative compression of the neck should be prevented by avoiding any circumferential tracheostomy ties or oxygen masks.
6. The head of the bed should be elevated at all times for best venous drainage.
7. In esophageal reconstruction, skin flaps (ALT and radial forearm) provide better speech outcomes than can be achieved with intestinal (jejunal) flaps.
8. When using a buried flap for esophageal reconstruction, an external monitoring segment (such as a perforator skin island or an exteriorized segment of jejunum) should be considered.
Chapter 3  Guide to Flap Selection  •  Neck

### Flap Choice

Flaps are listed in order of popularity.

1. **Pectoralis major** (p. 518)
2. Supraclavicular (p. 546)
3. Deltopectoral (p. 432)
4. Submental (p. 388)
5. Trapezius (p. 694)
6. Latissimus (p. 726)
7. *Anterolateral thigh (ALT)* (p. 1350)
8. **Radial forearm** (p. 842)
9. Free muscle/skin
10. Jejunal (p. 1298)

### Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial temporal
2. Facial
3. Lingual
4. Superior thyroid
5. External carotid
6. Transverse cervical
7. Thoracoacromial
8. Cephalic vein turnover
9. External jugular vein
10. Internal jugular vein

### Things to Consider When Reconstructing the Neck

1. The intraoral space should be separated and sealed from the neck.
2. The neck is a highly mobile area, so one must take into account the full neck motions.
3. Use of a shoulder roll facilitates neck exposure.
4. Microsurgery should be performed with the neck turned toward the opposite side to prevent postoperative tension on the microsurgery site.
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8. When using a buried flap for esophageal reconstruction, an external monitoring segment (such as a perforator skin island or an exteriorized segment of jejunum) should be considered.

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Red type denotes a workhorse flap.

*Italic type denotes a free flap.*
Flap Choice

1. Latissimus dorsi (p. 726)
2. Pectoralis major (p. 518)
3. Scapular/parascapular (p. 646)
4. Trapezius (p. 694)
5. Serratus anterior (p. 492)
6. Intercostal artery perforator (ICAP) (p. 474)
7. Lateral arm (p. 778)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Thoracodorsal
2. Thoracoacromial
3. Lateral thoracic
4. Axillary
5. Circumflex scapular
6. Transverse cervical
7. Cephalic vein

Things to Consider When Reconstructing the Shoulder

1. Local flaps and skin grafts are most commonly used.
2. The shoulder is a highly mobile area, so shoulder motion must be factored into the flap design.
3. A latissimus dorsi flap can reach to the elbow, even when tunneled.
4. One must beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
5. Use of a sling will prevent unintended postoperative motion.
6. Radiation may cause pedicle damage to axilla-based flaps.
Chapter 3  Guide to Flap Selection  •  Shoulder

Flap Choice

Flaps are listed in order of popularity.

1. **Latissimus dorsi** (p. 726)
2. **Pectoralis major** (p. 518)
3. **Scapular/parascapular** (p. 646)
4. **Trapezius** (p. 694)
5. **Serratus anterior** (p. 492)
6. **Intercostal artery perforator (ICAP)** (p. 474)
7. **Lateral arm** (p. 778)
8. **Free muscle/skin**

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. **Thoracodorsal**
2. **Thoracoacromial**
3. **Lateral thoracic**
4. **Axillary**
5. **Circumflex scapular**
6. **Transverse cervical**
7. **Cephalic vein**

Things to Consider When Reconstructing the Shoulder

1. Local flaps and skin grafts are most commonly used.
2. The shoulder is a highly mobile area, so shoulder motion must be factored into the flap design.
3. A latissimus dorsi flap can reach to the elbow, even when tunneled.
4. One must beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
5. Use of a sling will prevent unintended postoperative motion.
6. Radiation may cause pedicle damage to axilla-based flaps.

Red type denotes a workhorse flap.

*Italic type denotes a free flap.*
**Axilla Reconstruction Options**

**Flap Choice**
Flaps are listed in order of popularity.

1. Scapular/parascapular (p. 646)
2. Latissimus dorsi (p. 726)
3. Intercostal artery perforator (ICAP) (p. 474)
4. Free skin
5. Lateral arm (p. 778)
6. Serratus anterior (p. 492)

**Recipient Vessels**
Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Thoracodorsal
2. Axillary
3. Circumflex scapular
4. Lateral thoracic
5. Brachial
6. Transverse cervical
7. Cephalic vein

**Things to Consider When Reconstructing the Axilla**

1. One should not underestimate the amount of surface area the axilla requires. A template should be created with the patient’s arm completely extended.
2. The parascapular design is favored over the scapular design, because less rotation is necessary to reach the recipient site.
3. A modified sling that keeps the arm abducted will prevent postoperative motion and compression of the flap.
4. Thinner flaps allow the best unencumbered motion.
5. The surgeon should beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
# Flap Choice

Flaps are listed in order of popularity.

1. **Scapular/parascapular** (p. 646)
2. **Latissimus dorsi** (p. 726)
3. Intercostal artery perforator (ICAP) (p. 474)
4. **Free skin**
5. Lateral arm (p. 778)
6. Serratus anterior (p. 492)

# Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Thoracodorsal
2. Axillary
3. Circumflex scapular
4. Lateral thoracic
5. Brachial
6. Transverse cervical
7. Cephalic vein

### Things to Consider When Reconstructing the Axilla

1. One should not underestimate the amount of surface area the axilla requires. A template should be created with the patient’s arm completely extended.
2. The parascapular design is favored over the scapular design, because less rotation is necessary to reach the recipient site.
3. A modified sling that keeps the arm abducted will prevent postoperative motion and compression of the flap.
4. Thinner flaps allow the best unencumbered motion.
5. The surgeon should beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.

*Red type denotes a workhorse flap.  
Italic type denotes a free flap.*
Free Flap

Upper Arm Reconstruction Options

Flap Choice
Flaps are listed in order of popularity.
1. Latissimus dorsi (p. 726)
2. Scapular/parascapular (p. 646)
3. Lateral arm (p. 778)
4. Radial forearm (p. 842)
5. Free muscle/skin

Recipient Vessels
Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Brachial
2. Posterior circumflex humeral
3. Superior ulnar collateral
4. Radial collateral
5. Cephalic vein
6. Basilic vein

Things to Consider When Reconstructing the Upper Arm
1. A sling should be used to prevent unintended postoperative motion.
2. End-to-side anastomoses with the brachial artery will maintain distal perfusion.
3. The surgeon should beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
4. Cephalic and basilic veins are easiest to use for venous outflow.
Flap Choice

Flaps are listed in order of popularity.
1. Latissimus dorsi (p. 726)
2. Scapular/parascapular (p. 646)
3. Lateral arm (p. 778)
4. Radial forearm (p. 842)
5. Free muscle/skin

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Brachial
2. Posterior circumflex humeral
3. Superior ulnar collateral
4. Radial collateral
5. Cephalic vein
6. Basilic vein

Things to Consider When Reconstructing the Upper Arm

1. A sling should be used to prevent unintended postoperative motion.
2. End-to-side anastomoses with the brachial artery will maintain distal perfusion.
3. The surgeon should beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
4. Cephalic and basilic veins are easiest to use for venous outflow.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Elbow Reconstruction Options

Flap Choice
1. Lateral arm (reverse) flap (p. 778)
2. Radial forearm flap (p. 842)
3. Latissimus dorsi flap (p. 726)
4. Ulnar forearm flap (p. 894)
5. Flexor carpi ulnaris (FCU) flap (p. 880)
6. Groin flap (p. 1242)

Recipient Vessels
1. Brachial
2. Radial
3. Ulnar
4. Cephalic vein
5. Basilic vein

Things to Consider When Reconstructing the Elbow
1. The elbow is a highly mobile area, so one must be sure to account for elbow flexion and extension.
2. One should not underestimate the amount of surface area the elbow requires for full range of motion.
3. A template should be created with the patient’s elbow completely flexed.
4. Use of a sling will prevent unintended postoperative motion.
5. End-to-side anastomoses with the brachial artery will maintain distal perfusion.
6. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.
### Flap Choice

Flaps are listed in order of popularity.

1. **Lateral arm (reverse)** (p. 778)
2. **Radial forearm** (p. 842)
3. **Latissimus dorsi** (p. 726)
4. **Ulnar forearm** (p. 894)
5. **Flexor carpi ulnaris (FCU)** (p. 880)
6. **Groin** (p. 1242)
7. **Free skin**

### Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. **Brachial**
2. **Radial**
3. **Ulnar**
4. **Cephalic vein**
5. **Basilic vein**

### Things to Consider When Reconstructing the Elbow

1. The elbow is a highly mobile area, so one must be sure to account for elbow flexion and extension.
2. One should not underestimate the amount of surface area the elbow requires for full range of motion. A template should be created with the patient’s elbow completely flexed.
3. Use of a sling will prevent unintended postoperative motion.
4. End-to-side anastomoses with the brachial artery will maintain distal perfusion.
5. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.

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*Red type denotes a workhorse flap.*

*Italic type denotes a free flap.*
Free Flap

Antecubital Fossa Reconstruction Options

Flap Choice

1. Lateral arm (reverse) (p. 778)
2. Radial forearm (p. 842)
3. Ulnar forearm (p. 894)
4. Flexor carpi ulnaris (FCU) (p. 880)
5. Free skin/fascia

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Brachial
2. Radial
3. Ulnar
4. Cephalic vein
5. Basilic vein

Things to Consider When Reconstructing the Antecubital Fossa

1. One should not underestimate the amount of surface area the antecubital area requires. A template should be created with the patient’s arm completely extended.
2. A modified sling that keeps the elbow between 90 and 180 degrees will prevent postoperative motion and compression of the flap.
3. Thinner flaps allow the best unencumbered motion.
4. A gliding surface should be considered in flap choice when tendons are exposed.

Lateral arm (reverse) flap
Radial forearm flap
Ulnar forearm flap
Flexor carpi ulnaris (FCU) flap
Chapter 3  Guide to Flap Selection  •  Antecubital Fossa

### Flap Choice

Flaps are listed in order of popularity.
1. **Lateral arm (reverse)** (p. 778)
2. **Radial forearm** (p. 842)
3. **Ulnar forearm** (p. 894)
4. **Flexor carpi ulnaris (FCU)** (p. 880)
5. **Free skin/fascia**

### Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. **Brachial**
2. **Radial**
3. **Ulnar**
4. **Cephalic vein**
5. **Basilic vein**

### Things to Consider When Reconstructing the Antecubital Fossa

1. One should not underestimate the amount of surface area the antecubital area requires. A template should be created with the patient’s arm completely extended.
2. A modified sling that keeps the elbow between 90 and 180 degrees will prevent postoperative motion and compression of the flap.
3. Thinner flaps allow the best unencumbered motion.
4. A gliding surface should be considered in flap choice when tendons are exposed.

---

**Red type denotes a workhorse flap.**

**Italic type denotes a free flap.**
Free Flap

Forearm Reconstruction Options

1. Radial forearm (p. 842)
2. Ulnar forearm (p. 894)
3. Lateral arm (reverse) (p. 778)
4. Posterior interosseous (p. 820)
5. Groin (p. 1242)
6. Brachioradialis (p. 806)
7. Free muscle/skin/fascia/bone

Recipient Vessels

1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

Things to Consider When Reconstructing the Forearm

1. Postoperative elevation limits edema.
2. A sling will prevent unintended postoperative motion.
3. A preoperative Allen’s test should be performed before the ulnar or radial arteries are sacrificed.
4. End-to-side anastomoses should be considered with either artery when possible to maintain distal perfusion.
5. The radial artery is easier to dissect and reduces the known complications of ulnar neurapraxias that can occur with ulnar artery dissection.
6. Cephalic and basilic veins should be used for primary or secondary venous anastomosis.
7. A gliding surface should be considered in flap choice when tendons are exposed.
8. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.
**Flap Choice**

Flaps are listed in order of popularity.

1. **Radial forearm** (p. 842)
2. Ulnar forearm (p. 894)
3. Lateral arm (reverse) (p. 778)
4. Posterior interosseous (p. 820)
5. Groin (p. 1242)
6. Brachioradialis (p. 806)
7. *Free muscle/skin/fascia/bone*

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

**Things to Consider When Reconstructing the Forearm**

1. Postoperative elevation limits edema.
2. A sling will prevent unintended postoperative motion.
3. A preoperative Allen’s test should be performed before the ulnar or radial arteries are sacrificed.
4. End-to-side anastomoses should be considered with either artery when possible to maintain distal perfusion.
5. The radial artery is easier to dissect and reduces the known complications of ulnar neurapraxias that can occur with ulnar artery dissection.
6. Cephalic and basilic veins should be used for primary or secondary venous anastomosis.
7. A gliding surface should be considered in flap choice when tendons are exposed.
8. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.

*Red type denotes a workhorse flap.*

*Italic type denotes a free flap.*
**Free Flap**

### Wrist Reconstruction Options

#### Flap Choice
- 1. Radial forearm (reverse) (p. 842)
- 2. Posterior interosseous (p. 820)
- 3. Groin (p. 1242)
- 4. Ulnar forearm (reverse) (p. 894)
- 5. Brachioradialis (p. 806)
- 6. Free skin/fascia/bone

#### Recipient Vessels
- Implies artery and vein unless otherwise noted.
- 1. Radial
- 2. Ulnar
- 3. Cephalic vein
- 4. Basilic vein

### Things to Consider When Reconstructing the Wrist
1. Postoperative elevation limits edema.
2. Use of a sling will prevent unintended postoperative motion.
3. A preoperative Allen's test should be performed before the ulnar or radial arteries are sacrificed.
4. A gliding surface should be considered in flap choice when tendons are exposed.
5. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.
**Flap Choice**

Flaps are listed in order of popularity.

1. Radial forearm (reverse) (p. 842)
2. Posterior interosseous (p. 820)
3. Groin (p. 1242)
4. Ulnar forearm (reverse) (p. 894)
5. Brachioradialis (p. 806)
6. Free skin/fascia/bone

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

**Things to Consider When Reconstructing the Wrist**

1. Postoperative elevation limits edema.
2. Use of a sling will prevent unintended postoperative motion.
3. A preoperative Allen’s test should be performed before the ulnar or radial arteries are sacrificed.
4. A gliding surface should be considered in flap choice when tendons are exposed.
5. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Hand Reconstruction Options

Flap Choice

1. Posterior interosseous (p. 820)
2. Radial forearm (reverse) (p. 842)
3. Ulnar forearm (reverse) (p. 894)
4. Groin (p. 1242)
5. Abductor digiti minimi (ADM) (p. 914)
6. Medial plantar (p. 1812)
7. Free muscle/skin/fascia

Recipient Vessels

Implies artery and vein unless otherwise noted.

1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

Things to Consider When Reconstructing the Hand

1. Function takes priority over cosmesis.
2. One should prefer sensate flaps in the hand.
3. A preoperative Allen’s test should be performed before the ulnar or radial arteries are sacrificed.
4. Postoperative physical therapy is as important as flap choice.
5. Postoperative elevation limits edema.
6. Use of a sling will prevent unintended postoperative motion.
7. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.

Free Flaps

Medial plantar

Free muscle/skin/fascia

Posterior interosseous flap

Radial forearm flap (reverse)

Ulnar forearm flap (reverse)

Abductor digiti minimi (ADM) flap

Groin flap
Flap Choice

Flaps are listed in order of popularity.
1. Posterior interosseous (p. 820)
2. Radial forearm (reverse) (p. 842)
3. Ulnar forearm (reverse) (p. 894)
4. Groin (p. 1242)
5. Abductor digiti minimi (ADM) (p. 914)
6. Medial plantar (p. 1812)
7. Free muscle/skin/fascia

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

Things to Consider When Reconstructing the Hand

1. Function takes priority over cosmesis.
2. One should prefer sensate flaps in the hand.
3. A preoperative Allen’s test should be performed before the ulnar or radial arteries are sacrificed.
4. Postoperative physical therapy is as important as flap choice.
5. Postoperative elevation limits edema.
6. Use of a sling will prevent unintended postoperative motion.
7. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Digit Reconstruction Options

Free Flap

Kleinert-Atasoy V-Y flap
Dorsal metacarpal flap
Cross-finger flap
Posterior interosseous flap
Homodigital neurovascular (Littler) island flap

Recipient vessels

1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

Things to Consider When Reconstructing the Digit

1. Postoperative elevation limits edema.
2. Use of a sling will prevent unintended postoperative motion.
3. Postoperative physical therapy is as important as flap choice.
4. Isolated transverse pulp defects often achieve superior aesthetic and functional outcomes when allowed to heal secondarily.
5. Nail bed injuries should be meticulously repaired to prevent nail deformities.
6. The advantage of augmenting tip defects is to prevent parrot-beaking of the nail.
Flap Choice

Flaps are listed in order of popularity.
1. Kleinert-Atasoy V-Y (p. 1074)
2. Dorsal metacarpal (p. 1010)
3. Cross-finger (p. 1046)
4. Homodigital neurovascular (Littler) island (p. 958)
5. Posterior interosseous (p. 820)
6. Second toe (p. 976)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Radial
2. Ulnar
3. Cephalic vein
4. Basilic vein

Things to Consider When Reconstructing the Digit

1. Postoperative elevation limits edema.
2. Use of a sling will prevent unintended postoperative motion.
3. Postoperative physical therapy is as important as flap choice.
4. Isolated transverse pulp defects often achieve superior aesthetic and functional outcomes when allowed to heal secondarily.
5. Nail bed injuries should be meticulously repaired to prevent nail deformities.
6. The advantage of augmenting tip defects is to prevent parrot-beaking of the nail.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Free Flaps

Thumb Reconstruction Options

Recipient Vessels
Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Radial
2. Princeps pollicis
3. Cephalic vein

Things to Consider When Reconstructing the Thumb
1. Postoperative elevation limits edema.
2. Use of a sling will prevent unintended postoperative motion.
3. Postoperative physical therapy is as important as flap choice.
4. A functional thumb is essential to a functional hand.
5. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.
Flap Choice

Flaps are listed in order of popularity.
1. Moberg advancement (p. 1090)
2. Posterior interosseous (p. 820)
3. Dorsal metacarpal (p. 1010)
4. Groin (p. 1242)
5. Great toe (p. 926)
6. Second toe (p. 976)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Radial
2. Princeps pollicis
3. Cephalic vein

Things to Consider When Reconstructing the Thumb

1. Postoperative elevation limits edema.
2. Use of a sling will prevent unintended postoperative motion.
3. Postoperative physical therapy is as important as flap choice.
4. A functional thumb is essential to a functional hand.
5. The ipsilateral groin should not be used for skin or vein grafts, because the area should be preserved for potential groin flap salvage in case of a complication or flap failure.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Free Flap

Anterior Chest Reconstruction Options

1. Pectoralis major (p. 518)
2. Rectus abdominis (p. 1136)
3. Latissimus dorsi (p. 726)
4. External oblique (p. 1192)
5. Intercostal artery perforator (ICAP) (p. 474)
6. Serratus anterior (p. 492)
7. Deltopectoral (p. 432)
8. Omental (p. 1324)
9. Free muscle/skin/fascia

Recipient Vessels

Implies artery and vein unless otherwise noted.
1. Internal mammary
2. Transverse cervical
3. Thoracodorsal
4. Thoracoacromial
5. Axillary
6. External jugular turnover
7. Cephalic turnover
8. Lateral thoracic vein

Things to Consider When Reconstructing the Anterior Chest

1. Reconstruction can affect pulmonary dynamics postoperatively, so aggressive pulmonary toilet is indicated.
2. If more than three rib segments are missing, a flail segment may result that warrants structural reconstruction.
3. For intrathoracic reconstructions, more chest wall should be resected to allow direct passage of the flap from its vascular pedicle.
4. Careful flap planning allows multiple flaps to be harvested in the same patient (supraclavicular, deltopectoral, and pectoralis major).
5. The combination of vertical rectus abdominis, external oblique, and/or latissimus flaps can close almost any anterior chest wound.
6. The mammary recipient site has fewer problems than the axillary recipient site relating to motion and compression postoperatively.
7. One should beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
Chapter 3  Guide to Flap Selection  •  Anterior Chest

Flap Choice

Flaps are listed in order of popularity.
1. Pectoralis major (p. 518)
2. Rectus abdominis (p. 1136)
3. Latissimus dorsi (p. 726)
4. External oblique (p. 1192)
5. Intercostal artery perforator (ICAP) (p. 474)
6. Serratus anterior (p. 492)
7. Deltopectoral (p. 432)
8. Omental (p. 1324)
9. Free muscle/skin/fascia

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Internal mammary
2. Transverse cervical
3. Thoracodorsal
4. Thoracoacromial
5. Axillary
6. External jugular turndown
7. Cephalic turnover
8. Lateral thoracic vein

Things to Consider When Reconstructing the Anterior Chest

1. Reconstruction can affect pulmonary dynamics postoperatively, so aggressive pulmonary toilet is indicated.
2. If more than three rib segments are missing, a flail segment may result that warrants structural reconstruction.
3. For intrathoracic reconstructions, more chest wall should be resected to allow direct passage of the flap from its vascular pedicle.
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5. The combination of vertical rectus abdominis, external oblique, and/or latissimus flaps can close almost any anterior chest wound.
6. The mammary recipient site has fewer problems than the axillary recipient site relating to motion and compression postoperatively.
7. One should beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Free Flaps

Breast Reconstruction Options

Flap Choice

Flaps are listed in order of popularity.
1. Rectus abdominis (TRAM) (p. 1136)
2. Latissimus dorsi (p. 726)
3. Pectoralis major (p. 518)
4. TRAM/DIEP/SIEA (pp. 1136, 1218)
5. Gracilis/TUG (p. 1418)
6. Gluteus/GAP (p. 584)
7. Lumbar perforator
8. Deep circumflex iliac artery (DCIA) (Rubens) (p. 1108)
9. Intercostal artery perforator (ICAP) (p. 474)

Recipient Vessels

Recipient vessels are listed in order of popularity.
Implies artery and vein unless otherwise noted.
1. Internal mammary
2. Thoracodorsal
3. Serratus branch, thoracodorsal
4. External jugular turndown
5. Cephalic turnover
6. Transverse cervical
7. Thoracoacromial
8. Axillary
9. Lateral thoracic vein

Things to Consider When Reconstructing the Breast

1. Adequate vascularity of the breast skin envelope must be ensured before removal of flap skin, especially in immediate reconstruction cases.
2. The mammary system can be successfully used both anterograde and retrograde, accommodating two arterial and two venous anastomoses.
3. Securing the flap to the chest wall is important to prevent unintended postoperative tension on the flap when the patient is moving or standing erect.
4. One must beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
5. Use of the axillary vessels should be reconsidered if a lymph node dissection is contemplated for the future.
Flap Choice

Flaps are listed in order of popularity.
1. **Rectus abdominis (TRAM)** (p. 1136)
2. **Latissimus dorsi** (p. 726)
3. **Pectoralis major** (p. 518)
4. **TRAM/DIEP/SIEA** (pp. 1136, 1218)
5. **Gracilis/TUG** (p. 1418)
6. **Gluteus/GAP** (p. 584)
7. **Lumbar perforator** (p. 676)
8. **Deep circumflex iliac artery (DCIA)** *(Rubens)* (p. 1108)
9. **Intercostal artery perforator (ICAP)** (p. 474)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Internal mammary
2. Thoracodorsal
3. Serratus branch, thoracodorsal
4. External jugular turndown
5. Cephalic turnover
6. Transverse cervical
7. Thoracoacromial
8. Axillary
9. Lateral thoracic vein

Things to Consider When Reconstructing the Breast

1. Adequate vascularity of the breast skin envelope must be ensured before removal of flap skin, especially in immediate reconstruction cases.
2. The mammary system can be successfully used both anterograde and retrograde, accommodating two arterial and two venous anastomoses.
3. Securing the flap to the chest wall is important to prevent unintended postoperative tension on the flap when the patient is moving or standing erect.
4. One must beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
5. Use of the axillary vessels should be reconsidered if a lymph node dissection is contemplated for the future.

Red type denotes a workhorse flap.
*Italic* type denotes a free flap.
Intrathoracic Region Reconstruction Options

Flap Choice
- Latissimus dorsi (p. 726)
- Serratus anterior (p. 492)
- Pectoralis major (p. 518)
- Omental (p. 1324)
- Rectus abdominis (p. 1136)

Recipient Vessels
- Internal mammary
- Thoracodorsal
- Thoracoacromial
- Transverse cervical
- Cephalic vein turnover
- Lateral thoracic vein

Things to Consider When Reconstructing the Intrathoracic Region
1. The rib segment nearest to the vascular pedicle should be removed to maximize the flap length and volume available for reconstruction.
2. There is not enough tissue to completely obliterate a pneumonectomy defect without thoracic cage modification (thoracoplasty).
3. Flap position can be maintained with sutures and tissue glues.
4. One must beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.
# Flap Choice

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# Recipient Vessels

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<td>Cephalic vein turnover</td>
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<td>Lateral thoracic vein</td>
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</table>

# Things to Consider When Reconstructing the Intrathoracic Region

1. The rib segment nearest to the vascular pedicle should be removed to maximize the flap length and volume available for reconstruction.
2. There is not enough tissue to completely obliterate a pneumonectomy defect without thoracic cage modification (thoracoplasty).
3. Flap position can be maintained with sutures and tissue glues.
4. One must beware of previous lymph node dissections, because some vessels may have been divided; dilated veins should be explored before use.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Flap Choice

1. Tensor fascia lata (TFL) (p. 1506)
2. Rectus femoris (p. 1552)
3. Anterolateral thigh (ALT) (p. 1350)
4. Rectus abdominis (p. 1136)
5. Groin (SCIA) (p. 1242)
6. Superficial inferior epigastric artery (SIEA) (p. 1218)
7. External oblique (p. 1192)
8. Thoracoepigastric (p. 1268)
9. Omental (p. 1324)
10. Free muscle/skin/fascia

Recipient Vessels

1. Deep inferior epigastric
2. Superficial epigastric
3. Superior epigastric
4. Superficial circumflex iliac
5. Deep circumflex iliac
6. Right and left epiploic
7. Greater saphenous vein turnover

Things to Consider When Reconstructing the Abdomen

1. Abdominal integrity at closure is critical to a successful postoperative course and prevention of future hernias and bulges.
2. Mesh should be used as needed to ensure a dependable fascial closure.
3. Postoperative binder use can limit edema and support flaps as they heal.
4. Six to 8 weeks should be allowed before stressing an abdominal fascial closure.
5. Because of the lack of bony confines, one can take advantage of the horizontal excess present in all abdomens and close surprisingly large donor sites.
6. Bowel management and avoidance of postoperative bloating and constipation will limit unnecessary tension on abdominal wall reconstructions.
Flap Choice

Flaps are listed in order of popularity.

1. **Tensor fascia lata (TFL)** (p. 1506)
2. **Rectus femoris** (p. 1552)
3. **Anterolateral thigh (ALT)** (p. 1350)
4. **Rectus abdominis** (p. 1136)
5. **Groin (SCIA)** (p. 1242)
6. **Superficial inferior epigastric artery (SIEA)** (p. 1218)
7. **External oblique** (p. 1192)
8. **Thoracoepigastric** (p. 1268)
9. **Omental** (p. 1324)
10. **Free muscle/skin/fascia**

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. **Deep inferior epigastric**
2. **Superficial epigastric**
3. **Superior epigastric**
4. **Superficial circumflex iliac**
5. **Deep circumflex iliac**
6. **Right and left epiploic**
7. **Greater saphenous vein turnover**

Things to Consider When Reconstructing the Abdomen

1. Abdominal integrity at closure is critical to a successful postoperative course and prevention of future hernias and bulges.
2. Mesh should be used as needed to ensure a dependable fascial closure.
3. Postoperative binder use can limit edema and support flaps as they heal.
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5. Because of the lack of bony confines, one can take advantage of the horizontal excess present in all abdomens and close surprisingly large donor sites.
6. Bowel management and avoidance of postoperative bloating and constipation will limit unnecessary tension on abdominal wall reconstructions.

Red type denotes a workhorse flap. 
*Italic type denotes a free flap.*
Free Flap

Groin Reconstruction Options

Flap Choice
Flaps are listed in order of popularity.
1. Sartorius (p. 1466)
2. Tensor fascia lata (TFL) (p. 1506)
3. Rectus femoris (p. 1552)
4. Anterolateral thigh (ALT) (p. 1350)
5. Vastus lateralis (p. 1534)
6. Rectus abdominis (p. 1136)
7. Thoracoepigastric (p. 1268)
8. Gracilis (p. 1418)
9. Free skin

Recipient Vessels
Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Deep inferior epigastric
2. Superficial epigastric
3. Superficial circumflex iliac
4. Deep circumflex iliac
5. Femoral
6. External iliac
7. Greater saphenous vein turnover

Things to Consider When Reconstructing the Groin
1. Flaps should obliterate dead space.
2. Because of the presence of lymphatics that are often violated, the groin should be drained well; the drains are kept in place until the flap−recipient site interface has sealed.
3. Further lymphatic dissection and injury should be avoided to prevent postoperative lymphedema.
4. If a vascular repair has been performed or vessels have been divided, inflow to the planned flap may be insufficient.
5. Fascial replacement may be needed if the inguinal ligament has been taken down to avoid hernia postoperatively. Plan a flap with fascia (tensor fascia lata, rectus femoris, rectus abdominis) or use synthetic mesh under a well-vascularized flap.

<table>
<thead>
<tr>
<th>Flap Description</th>
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<tbody>
<tr>
<td>Sartorius</td>
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<td>Gracilis</td>
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Free skin

Tensor fascia lata (TFL) flap
Anterolateral thigh (ALT) flap
Rectus femoris flap
Vastus lateralis flap
Gracilis flap
Sartorius flap
Thoracoepigastric flap
Rectus abdominis flap
Flap Choice

Flaps are listed in order of popularity.
1. **Sartorius** (p. 1466)
2. **Tensor fascia lata (TFL)** (p. 1506)
3. **Rectus femoris** (p. 1552)
4. **Anterolateral thigh (ALT)** (p. 1350)
5. **Vastus lateralis** (p. 1534)
6. **Rectus abdominis** (p. 1136)
7. **Thoracoepigastric** (p. 1268)
8. **Gracilis** (p. 1418)
9. **Free skin**

Recipient Vessels

Recipient vessels are listed in order of popularity.
1. Deep inferior epigastric
2. Superficial epigastric
3. Superficial circumflex iliac
4. Deep circumflex iliac
5. Femoral
6. External iliac
7. Greater saphenous vein turnover

Things to Consider When Reconstructing the Groin

1. Flaps should obliterate dead space.
2. Because of the presence of lymphatics that are often violated, the groin should be drained well; the drains are kept in place until the flap–recipient site interface has sealed.
3. Further lymphatic dissection and injury should be avoided to prevent postoperative lymphedema.
4. If a vascular repair has been performed or vessels have been divided, inflow to the planned flap may be insufficient.
5. Fascial replacement may be needed if the inguinal ligament has been taken down to avoid hernia postoperatively. Plan a flap with fascia (tensor fascia lata, rectus femoris, rectus abdominis) or use synthetic mesh under a well-vascularized flap.

Red type denotes a workhorse flap.

*Italic type denotes a free flap.*
Flap Choice

1. Rectus abdominis (p. 1136)
2. Pudendal-thigh (Singapore) (p. 1280)
3. Gracilis (p. 1418)
4. Gluteal thigh (p. 620)
5. Anterolateral thigh (ALT) (p. 1350)
6. Jejunal (p. 1298)
7. Groin (p. 1242)
8. Superficial inferior epigastric artery (SIEA) (p. 1218)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Deep inferior epigastric
2. Superficial epigastric
3. Superficial circumflex iliac
4. Deep circumflex iliac
5. Femoral
6. External iliac
7. Greater saphenous vein turnover

Things to Consider When Reconstructing the Vaginal Vault

1. Because of the tendency of flap shrinkage in this area, the surgeon must ensure that a flap of adequate length is used.
2. The anterior vaginal remnant that is often preserved after resection should be incorporated in the reconstruction.
3. The introitus should be made as patulous as possible to prevent postoperative stenosis.
4. When possible, sensate flaps (pudendal, thigh, gluteal) are preferred for reconstructing the vaginal vault.
**Flap Choice**

Flaps are listed in order of popularity.

1. **Rectus abdominis** (p. 1136)
2. **Pudendal-thigh** (Singapore) (p. 1280)
3. **Gracilis** (p. 1418)
4. **Gluteal thigh** (p. 620)
5. **Anterolateral thigh** (ALT) (p. 1350)
6. **Jejunal** (p. 1298)
7. **Groin** (p. 1242)
8. **Superficial inferior epigastric artery** (SIEA) (p. 1218)

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Deep inferior epigastric
2. Superficial epigastric
3. Superficial circumflex iliac
4. Deep circumflex iliac
5. Femoral
6. External iliac
7. Greater saphenous vein turnover

**Things to Consider When Reconstructing the Vaginal Vault**

1. Because of the tendency of flap shrinkage in this area, the surgeon must ensure that a flap of adequate length is used.
2. The anterior vaginal remnant that is often preserved after resection should be incorporated in the reconstruction.
3. The introitus should be made as patulous as possible to prevent postoperative stenosis.
4. When possible, sensate flaps (pudendal, thigh, gluteal) are preferred for reconstructing the vaginal vault.

Red type denotes a workhorse flap. *Italic type denotes a free flap.*
Free Flap Reconstruction Options

Flap Choice

1. Latissimus dorsi (p. 726)
2. Scapular (p. 646)
3. Paraspinous (p. 758)
4. Trapezius (p. 694)
5. Intercostal artery perforator (ICAP) (p. 474)
6. Free muscle/skin

Recipient Vessels

Implies artery and vein unless otherwise noted.

1. Thoracodorsal
2. Circumflex scapular
3. Intercostal artery
4. A-V loop (axilla, neck)

Things to Consider When Reconstructing the Upper Back

1. The midline of the upper back is one of the hardest areas to reconstruct because there are a limited number of flaps that will reach this area.
2. There are no convenient recipient sites for free flaps.
3. The surgeon’s options may be limited to an intercostal artery recipient, which is small and has poor vae comitantes.
4. Tissue expansion can be a helpful adjunct procedure.
Flap Choice

Flaps are listed in order of popularity.
1. Latissimus dorsi (p. 726)
2. Scapular (p. 646)
3. Paraspinous (p. 758)
4. Trapezius (p. 694)
5. Intercostal artery perforator (ICAP) (p. 474)
6. Free muscle/skin

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Thoracodorsal
2. Circumflex scapular
3. Intercostal artery
4. A-V loop (axilla, neck)

Things to Consider When Reconstructing the Upper Back

1. The midline of the upper back is one of the hardest areas to reconstruct because there are a limited number of flaps that will reach this area.
2. There are no convenient recipient sites for free flaps.
3. The surgeon’s options may be limited to an intercostal artery recipient, which is small and has poor venae comitantes.
4. Tissue expansion can be a helpful adjunct procedure.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Free Flap

Lower Back
Reconstruction Options

Flap Choice

1. Latissimus dorsi (reverse) (p. 726)
2. Paraspinous (p. 758)
3. Lumbar perforator (p. 676)
4. Gluteus maximus (p. 584)
5. External oblique (p. 1192)
6. Free muscle/skin
7. Omental (p. 1324)

Recipient Vessels

Implies artery and vein unless otherwise noted.

1. Superior gluteal
2. Inferior gluteal
3. Intercostal artery
4. A-V loop (groin, thoracodorsal)

Things to Consider When Reconstructing the Lower Back

1. The midline of the lower back is one of the hardest areas to reconstruct because there are limited flaps that will reach this area.
2. There are no convenient recipient sites for free flaps; an A-V loop should be considered.
3. Tissue expansion can be a helpful adjunct procedure.
4. When available, the paraspinous flap offers the simplest means of closure for reconstruction of midline defects. Its utility decreases toward the sacrum.
5. Omentum may be tunneled through the paracolic gutter when other back flaps are unavailable.
6. The gluteal artery perforator (GAP) flap should be considered as a pedicle option for difficult back wounds.
Flap Choice

Flaps are listed in order of popularity.

1. Latissimus dorsi (reverse) (p. 726)
2. Paraspinous (p. 758)
3. Lumbar perforator (p. 676)
4. Gluteus maximus (p. 584)
5. External oblique (p. 1192)
6. Free muscle/skin
7. Omental (p. 1324)

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superior gluteal
2. Inferior gluteal
3. Intercostal artery
4. A-V loop (groin, thoracodorsal)

Things to Consider When Reconstructing the Lower Back

1. The midline of the lower back is one of the hardest areas to reconstruct because there are limited flaps that will reach this area.
2. There are no convenient recipient sites for free flaps; an A-V loop should be considered.
3. Tissue expansion can be a helpful adjunct procedure.
4. When available, the paraspinous flap offers the simplest means of closure for reconstruction of midline defects. Its utility decreases toward the sacrum.
5. Omentum may be tunneled through the paracolic gutter when other back flaps are unavailable.
6. The gluteal artery perforator (GAP) flap should be considered as a pedicle option for difficult back wounds.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Buttock Reconstruction Options

Flap Choice

Flaps are listed in order of popularity.
1. Gluteus maximus (p. 584)
2. Biceps femoris (hamstring) (p. 1482)
3. Gracilis (p. 1418)
4. Tensor fascia lata (TFL) (p. 1506)
5. Gluteal thigh (p. 620)
6. Vastus lateralis (p. 1534)
7. Lumbar perforator (p. 676)
8. Free muscle/skin

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Superior gluteal
2. Inferior gluteal
3. A-V loop (groin)

Things to Consider When Reconstructing the Buttock

1. For decubitis, dead space fill is as important as skin resurfacing.
2. The patient is instructed to avoid sitting directly on the reconstruction for 4 to 6 weeks.
3. Muscle sacrifice should be avoided in an ambulatory patient.
4. The surgeon should exercise great care to prevent any tension on the closure.
5. Deepithelization of the leading edge of the flap should be considered to provide additional bulk and fill to the reconstructed defect.
6. The gluteal artery perforator (GAP) flap should be the pedicle flap of choice for ambulatory patients.
Chapter 3  Guide to Flap Selection  •  Buttock

Flap Choice

Flaps are listed in order of popularity.
1. **Gluteus maximus** (p. 584)
2. **Biceps femoris (hamstring)** (p. 1482)
3. **Gracilis** (p. 1418)
4. **Tensor fascia lata (TFL)** (p. 1506)
5. **Gluteal thigh** (p. 620)
6. **Vastus lateralis** (p. 1534)
7. **Lumbar perforator** (p. 676)
8. **Free muscle/skin**

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. **Superior gluteal**
2. **Inferior gluteal**
3. **A-V loop (groin)**

Things to Consider When Reconstructing the Buttock

1. For decubiti, dead space fill is as important as skin resurfacing.
2. The patient is instructed to avoid sitting directly on the reconstruction for 4 to 6 weeks.
3. Muscle sacrifice should be avoided in an ambulatory patient.
4. The surgeon should exercise great care to prevent any tension on the closure.
5. Deepithelization of the leading edge of the flap should be considered to provide additional bulk and fill to the reconstructed defect.
6. The gluteal artery perforator (GAP) flap should be the pedicle flap of choice for ambulatory patients.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Free Flap

Thigh Reconstruction Options

Flap Choice
Flaps are listed in order of popularity.

1. Sartorius (p. 1466)
2. Gracilis (p. 1418)
3. Tensor fascia lata (TFL) (p. 1506)
4. Rectus femoris (p. 1552)
5. Vastus lateralis (p. 1534)
6. Biceps femoris (hamstring) (p. 1482)
7. Anterolateral thigh (ALT) (p. 1350)
8. Rectus abdominis (p. 1136)
9. Saphenous (p. 1392)
10. Gluteus maximus (p. 584)

Recipient Vessels
Recipient vessels are listed in order of popularity.

1. Superficial femoral
2. Lateral circumflex femoral
3. Medial circumflex femoral
4. Superficial epigastric
5. Superficial circumflex iliac
6. Profunda femoris
7. Greater saphenous vein

Things to Consider When Reconstructing the Thigh
1. The use of local muscles is often the best option.
2. The need for free flaps is rare.
3. For free flaps, consider end-to-side anastomoses to the major vessels to preserve distal blood flow.

Free muscle/skin
Tensor fascia lata (TFL) flap
Anterolateral thigh (ALT) flap
Rectus femoris flap
Vastus lateralis flap
Gluteus maximus flap
Rectus abdominis flap
Biceps femoris (hamstring) flap
**Flap Choice**

Flaps are listed in order of popularity.

1. Sartorius (p. 1466)
2. Gracilis (p. 1418)
3. Tensor fascia lata (TFL) (p. 1506)
4. Rectus femoris (p. 1552)
5. Vastus lateralis (p. 1534)
6. Biceps femoris (hamstring) (p. 1482)
7. Anterolateral thigh (ALT) (p. 1350)
8. Rectus abdominis (p. 1136)
9. Saphenous (p. 1392)
10. Gluteus maximus (p. 584)
11. *Free muscle/skin*

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Superficial femoral
2. Lateral circumflex femoral
3. Medial circumflex femoral
4. Superficial epigastric
5. Superficial circumflex iliac
6. Profunda femoris
7. Greater saphenous vein

**Things to Consider When Reconstructing the Thigh**

1. The use of local muscles is often the best option.
2. The need for free flaps is rare.
3. For free flaps, consider end-to-side anastomoses to the major vessels to preserve distal blood flow.

Red type denotes a workhorse flap.

*Italic type denotes a free flap.*
Knee Reconstruction Options

Flap Choice

Flaps are listed in order of popularity.
1. Gastrocnemius (p. 1682)
2. Anterolateral thigh (ALT) (reverse) (p. 1350)
3. Vastus lateralis (reverse) (p. 1534)
4. Saphenous (p. 1392)
5. Rectus femoris (p. 1552)
6. Tibialis anterior (p. 1706)
7. Free muscle/skin

Things to Consider When Reconstructing the Knee

1. The knee is a highly mobile area, so one must take range of motion into account in designing a flap.
2. The surgeon should not underestimate the amount of surface area the knee requires; a template should be created with the knee completely flexed.
3. A splint should be placed postoperatively to minimize motion with no pressure on flap.
4. The knee must remain elevated to reduce the inevitable swelling.
5. The medial gastrocnemius is preferred over the lateral gastrocnemius because it is larger and easier to transpose.
**Flap Choice**

Flaps are listed in order of popularity.
1. *Gastrocnemius* (p. 1682)
2. Anterolateral thigh (ALT) (reverse) (p. 1350)
3. Vastus lateralis (reverse) (p. 1534)
4. Saphenous (p. 1392)
5. Rectus femoris (p. 1552)
6. Tibialis anterior (p. 1706)
7. *Free muscle/skin*

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Popliteal
2. Sural
3. Genicular
4. Descending lateral circumflex
5. Superficial femoral
6. Greater saphenous vein
7. Lesser saphenous vein

**Things to Consider When Reconstructing the Knee**

1. The knee is a highly mobile area, so one must take range of motion into account in designing a flap.
2. The surgeon should not underestimate the amount of surface area the knee requires; a template should be created with the knee completely flexed.
3. A splint should be placed postoperatively to minimize motion with no pressure on flap.
4. The knee must remain elevated to reduce the inevitable swelling.
5. The medial gastrocnemius is preferred over the lateral gastrocnemius because it is larger and easier to transpose.

*Red type denotes a workhorse flap.*

*Italic type denotes a free flap.*
Free Flap

Poilital Fossa Reconstruction Options

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Popliteal
2. Sural
3. Genicular
4. Descending lateral circumflex
5. Superficial femoral
6. Greater saphenous vein
7. Lesser saphenous vein

Things to Consider When Reconstructing the Popliteal Fossa
1. The surgeon should not underestimate the amount of surface area the popliteal fossa requires; a template should be created with the leg completely extended.
2. A modified splint to keep the knee straight will prevent postoperative motion and allow elevation. The splint should prevent compression of the flap.
3. Thinner flaps allow the best unencumbered motion.
4. End-to-side anastomoses to the popliteal artery should be considered to preserve distal blood flow.
**Flap Choice**

Flaps are listed in order of popularity.
1. Gastrocnemius (p. 1682)
2. Saphenous (p. 1392)
3. Sural artery (p. 1654)
4. Tibialis anterior (p. 1706)
5. Free muscle/skin

**Recipient Vessels**

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Popliteal
2. Sural
3. Genicular
4. Descending lateral circumflex
5. Superficial femoral
6. Greater saphenous vein
7. Lesser saphenous vein

**Things to Consider When Reconstructing the Popliteal Fossa**

1. The surgeon should not underestimate the amount of surface area the popliteal fossa requires; a template should be created with the leg completely extended.
2. A modified splint to keep the knee straight will prevent postoperative motion and allow elevation. The splint should prevent compression of the flap.
3. Thinner flaps allow the best unencumbered motion.
4. End-to-side anastomoses to the popliteal artery should be considered to preserve distal blood flow.

*Red type denotes a workhorse flap.*

*Italic type denotes a free flap.*
Leg Reconstruction Options

Flap Choice

Flaps are listed in order of popularity.

1. Gastrocnemius (p. 1682)
2. Soleus (p. 1628)
3. Sural artery (reverse) (p. 1654)
4. Anterior tibialis (p. 1706)
5. Saphenous (p. 1392)
6. Dorsalis pedis (p. 1788)
7. Fibula (p. 1584)
8. Free muscle/skin/fascia/bone

Things to Consider When Reconstructing the Leg

1. The upper two thirds of the leg is amenable to local muscle flaps.
2. The lower third has some local options but is well reconstructed with free flaps.
3. Recipient vessels for free flaps should be sought outside the zone of injury, either proximally or distally.
4. When possible, two venous anastomoses should be performed for each arterial anastomosis, taking advantage of deep and superficial venous systems.
5. End-to-side anastomoses to the popliteal artery should be considered to preserve distal blood flow.
6. A preoperative arteriogram should be done when the clinical pulse examination is abnormal or a doubt exists about potential injury to the vessels.
7. An A-V loop to the popliteal vessels should be considered when the distal vessels are inadequate.
8. In a dysvascular patient, a revascularization procedure may be considered before or in combination with the flap surgery.
9. Fasciocutaneous and muscle flaps are equally effective for treating open wounds and resected osteomyelitis.
10. The leg should remain elevated, and ambulation should be limited in the early postoperative period.
Chapter 3  Guide to Flap Selection  •  Leg

Flap Choice

Flaps are listed in order of popularity.
1. Gastrocnemius (p. 1682)
2. Soleus (p. 1628)
3. Sural artery (reverse) (p. 1654)
4. Anterior tibialis (p. 1706)
5. Saphenous (p. 1392)
6. Dorsalis pedis (p. 1788)
7. Fibula (p. 1584)
8. Free muscle/skin/fascia/bone

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Posterior tibial
2. Anterior tibial
3. Peroneal
4. Popliteal
5. Dorsalis pedis
6. Greater saphenous vein
7. Lesser saphenous vein

Things to Consider When Reconstructing the Leg

1. The upper two thirds of the leg is amenable to local muscle flaps.
2. The lower third has some local options but is well reconstructed with free flaps.
3. Recipient vessels for free flaps should be sought outside the zone of injury, either proximally or distally.
4. When possible, two venous anastomoses should be performed for each arterial anastomosis, taking advantage of deep and superficial venous systems.
5. End-to-side anastomoses to the popliteal artery should be considered to preserve distal blood flow.
6. A preoperative arteriogram should be done when the clinical pulse examination is abnormal or a doubt exists about potential injury to the vessels.
7. An A-V loop to the popliteal vessels should be considered when the distal vessels are inadequate.
8. In a dysvascular patient, a revascularization procedure may be considered before or in combination with the flap surgery.
9. Fasciocutaneous and muscle flaps are equally effective for treating open wounds and resected osteomyelitis.
10. The leg should remain elevated, and ambulation should be limited in the early postoperative period.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
**Foot Reconstruction Options**

Flap Choice

Flaps are listed in order of popularity.
1. Sural artery (reverse) (p. 1661)
2. Tibialis anterior (p. 1706)
3. Dorsalis pedis (p. 1788)
4. Lateral calcaneal (p. 1834)
5. Medial plantar (p. 1218)
6. Abductor digiti minimi (ADM) (p. 1734)
7. Flexor digitorum brevis (FDB) (p. 1754)
8. Abductor hallucis (p. 1772)
9. Free muscle/skin/fascia

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.
1. Dorsalis pedis
2. Anterior tibial
3. Posterior tibial
4. Peroneal
5. Greater saphenous vein
6. Lesser saphenous vein

Things to Consider When Reconstructing the Foot

1. The foot is one of the hardest areas to reconstruct because of the distant nature of the blood supply, the increased venous pressure, and the impressive postoperative swelling that occurs at the surgical site.
2. Division of one of the three vessels to the leg and foot should only be performed when an alternative blood flow to the foot is confirmed.
3. An arteriogram is recommended if pulses are not palpable.
4. The specialized plantar surface requires durable reconstructive choices for areas of weight-bearing.
5. Muscle free flaps with skin graft are equal to free skin flaps in regard to wound healing, postoperative complications, and the patient’s resultant ability to ambulate.
6. Foot elevation with no weight-bearing is recommended for at least 4 weeks for most flap surgeries.
7. An external fixator should be placed at the time of surgery to maintain leg and foot position postoperatively, even if no bony injury exists.
Chapter 3  Guide to Flap Selection  •  Foot

Flap Choice

Flaps are listed in order of popularity.

1. Sural artery (reverse) (p. 1661)
2. Tibialis anterior (p. 1706)
3. Dorsalis pedis (p. 1788)
4. Lateral calcaneal (p. 1834)
5. Medial plantar (p. 1218)
6. Abductor digiti minimi (ADM) (p. 1734)
7. Flexor digitorum brevis (FDB) (p. 1754)
8. Abductor hallucis (p. 1772)
9. Free muscle/skin/fascia

Recipient Vessels

Recipient vessels are listed in order of popularity. Implies artery and vein unless otherwise noted.

1. Dorsalis pedis
2. Anterior tibial
3. Posterior tibial
4. Peroneal
5. Greater saphenous vein
6. Lesser saphenous vein

Things to Consider When Reconstructing the Foot

1. The foot is one of the hardest areas to reconstruct because of the distant nature of the blood supply, the increased venous pressure, and the impressive postoperative swelling that occurs at the surgical site.
2. Division of one of the three vessels to the leg and foot should only be performed when an alternative blood flow to the foot is confirmed.
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6. Foot elevation with no weight-bearing is recommended for at least 4 weeks for most flap surgeries.
7. An external fixator should be placed at the time of surgery to maintain leg and foot position postoperatively, even if no bony injury exists.

Red type denotes a workhorse flap.
Italic type denotes a free flap.
Considerations in Flap Selection

<table>
<thead>
<tr>
<th>Patient Factors</th>
<th>Flap Factors</th>
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<td>Willingness to accept scars</td>
<td>Component parts (muscle, skin, fascia, bone)</td>
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<td>Desired recovery time</td>
<td>Pedicle length</td>
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<tr>
<td>Patient reliability</td>
<td>Arc of rotation</td>
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</tbody>
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Local Factors
Location on the body
Previous surgery
Previous or anticipated radiation therapy
Tissue quality
Local tissue availability

Workhorse Flaps

<table>
<thead>
<tr>
<th>Fasciocutaneous Flaps</th>
<th>Bone</th>
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<tr>
<td>Temporoparietal fascia</td>
<td>Fibula (fibula flap)</td>
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<tr>
<td>Radial forearm</td>
<td>Iliac (deep circumflex iliac artery [DCIA] flap)</td>
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<td>Scapular/parascapular</td>
<td>Radius (radial forearm flap)</td>
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<td>Groin</td>
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<td>Lateral arm</td>
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<td>Deltoplexoral</td>
<td>Humerus (lateral arm flap)</td>
</tr>
<tr>
<td>Supraclavicular</td>
<td>Rib (pectoralis major, serratus anterior, or latissimus dorsi flap)</td>
</tr>
</tbody>
</table>

Muscle
Rectus abdominis
Latissimus dorsi
Gracilis
Pectoralis major
Gluteus maximus
Gastrocnemius

Perforator
Deep inferior epigastric perforator (DIEP)
Superficial inferior epigastric artery (SIEA)
Anterolateral thigh (ALT)
Anteromedial thigh (AMT)
Superior gluteal artery perforator (SGAP)
 Inferior gluteal artery perforator (IGAP)
Thoracodorsal artery perforator (TDAP)
Tensor fascia lata (TFL)
### Vascularized Bone Flaps

1. Fibula (p. 1584)
2. Deep circumflex iliac artery (DCIA) (iliac) (p. 1108)
3. Radial forearm (radius) (p. 842)
4. Scapular/parascapular (scapula) (p. 646)
5. Lateral arm (humerus) (p. 778)
6. Saphenous (medial femoral condyle) (p. 1392)
7. Temporoparietal fascia (TPFF) (cranium) (p. 262)
8. Dorsalis pedis (second metatarsal) (p. 1788)
9. Tensor fascia lata (TFL) (iliac) (p. 1506)
10. Anterior lateral thigh (ALT) (iliac) (p. 1350)
11. Trapezius (scapula) (p. 694)
12. Tibialis anterior (fibula) (p. 1706)
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Chapter 4

Complications: Avoidance and Treatment

Complications are an ever-present part of reconstructive surgery. The more experience we gain in the practice of our art, the less likely these complications become. Unfortunately, we can only gain this experience by encountering these problems and learning from them. Only by studying our own patients, facing up to our shortcomings, and dealing with them in an open and academic way will we reduce or eliminate potential complications.

Although the causes of surgical complications are numerous, they can be grouped into four broad categories: patient selection and preparation, selection of reconstructive procedure, intraoperative execution, and postoperative care. While many of these etiologic factors are common to all surgical procedures, we will review those relating particularly to flap reconstructive surgical procedures.

INFORMED CONSENT

No chapter on complications would be complete without a discussion of informed consent. A famous surgeon once said, “When you explain the possibility of a complication before the surgery, it is called informed consent. When you explain a complication after it has happened, it is called an excuse.” Medicine in general, and reconstructive surgery in particular, are not exact sciences, and complications happen. The real mistake is in not preparing the patient appropriately for a less than optimal outcome of a surgical procedure and not owning up to a postsurgical complication when it occurs. A well-prepared patient understands the reconstructive procedure he or she is about to undergo and the possible complications associated with that procedure. A well-prepared surgeon has thought about these complications and how to avoid them and has an established plan for treating them. Then, when a complication does occur, it is our duty as caregivers to ensure that our patients know that we can be relied on to get them through this problem. It is important to avoid minimizing the problem and to explain carefully how you and the patient will get through this together, and will face any future problems that may arise. You must become the patient’s advocate, directing and guiding care to achieve a successful outcome.
PATIENT SELECTION AND PREPARATION

Often in reconstructive surgery we cannot choose our patients. They may present with a problem such as a traumatic injury or cancer that requires immediate attention, and the responsibility of care falls on our shoulders. With such cases, there is little time to optimize the patient's status to ensure the best possible outcome. We accept morbidity, and we care for complications as they occur. In cases in which the surgeon is consulted for a reconstructive problem and there is the luxury of time, it is important to take the opportunity to optimize the patient’s condition for the upcoming surgical procedure.

As consultants, we are often not the primary caregiver for a prospective patient. The referral itself should not be construed as a clearance for surgery or an understanding on the part of the referring physician of what the surgical procedure actually entails. Determining a patient’s candidacy for surgery should be the first step in planning the procedure.

The surgeon must first assess any comorbidities or patient-specific considerations that could interfere with the healing process (see the box below). For patients undergoing adjuvant therapies for cancer or who are debilitated by recent trauma or illness, these problems may require resolution before the reconstructive procedure. Smokers should be instructed to stop smoking; both the literature and clinical experience show the detrimental effects of nicotine on the reconstruction as well as on donor site morbidity. A patient who is unwilling to stop smoking may be a patient who is unwilling to follow postoperative instructions and may be difficult to manage. The best approach is to make that individual a partner in the reconstructive effort. If you explain that a preexisting condition must be resolved or the patient must stop smoking to promote proper healing and to avoid complications or the need for secondary surgeries, the patient will often agree to comply with these requirements.

### Medical Issues Affecting Healing

- Ongoing adjuvant chemotherapy
- History of radiation therapy
- Ongoing medical conditions
  - Diabetes
  - Cardiovascular disease
  - Cerebrovascular disease
  - Recent trauma
- Smoking/nicotine use
- Nutritional state
- Steroid use
- Anticoagulant use
- Hypercoaguable state
- Obesity
- Psychosocial factors
Although our surgical training encompassed basic medical care and management, we are surgical specialists, and prolonged medical care that extends postoperatively out of the hospital is out of our area of expertise and practice. For some conditions, it is appropriate to partner with the patient’s other caregivers to provide comprehensive perioperative care. Metabolic conditions such as diabetes need to be under strict control, preoperatively as well as perioperatively. In some cases, consultation with an endocrinologist may be advisable. Patients who have been debilitated by their illness should have albumin, prealbumin, and transferrin assays as a rough gauge of their nutritional status. Deficiencies should be further investigated to ensure that the patient’s metabolic status is optimal for reconstructive surgery. Consultation with a nutritional specialist may be indicated. Patients on an aspirin or anticoagulant regimen should be evaluated by their prescribing physician to determine whether these can safely be discontinued during the perioperative period. Patients with previously failed flaps should undergo a workup by a hematologist for a hypercoagulable state. Patients receiving steroidal agents for medical conditions should receive vitamin A supplementation to aid in the healing process. When possible and if time permits, issues of obesity should be addressed. Ideally, the patient should be at a stable weight for elective reconstructive procedures. Equally important in patient selection and preparation is the patient’s emotional state and emotional preparation for surgery. The individual’s support network and the level of postoperative family support must be assessed. Patients are worried about time away from work, so a specific return-to-work plan can assuage this concern. Patients need to be confident that there is a well-thought-out recovery plan in place that will allow them to undergo reconstructive surgery, recover successfully, and return to work in a timely fashion. Helping to relieve the stressors the patient faces preoperatively will aid in the healing process postoperatively.

**SELECTION OF RECONSTRUCTIVE PROCEDURE**

Most complications related to flap selection and the reconstructive plan can be avoided by proper planning and prevention. Once the surgeon is armed with the knowledge of which flaps or reconstructive techniques are available to solve the problem (see Chapter 3), he or she examines the patient to determine which would be most appropriate. It is in taking the history and examining the patient that some common errors can be made, resulting in complications (see the box on p. 156). A complete history of past surgical procedures is essential and must be confirmed by a careful physical examination. Determining how the patient healed after previous surgeries and what complications occurred offers insight into potential healing issues. It is not uncommon for patients to forget previous surgical procedures or not admit to past laparoscopic or cosmetic procedures, but physical examination will show telltale signs that should be noted and documented. This may help to prevent a situation in which the surgeon begins to harvest a flap, only to encounter the signs of previous surgery that were not revealed in the patient’s history. Such an unforeseen discovery can have a significant impact on the reconstructive outcome.
### History and Physical Examination

**History**
- Complete surgical history
  - Minimally invasive
  - Cosmetic
- Past complications and their management
- Risk factors for DVT

**Physical Examination**
Examination of all previous scars
- Hypertrophic or keloid
- Hernias or bulges
- Related neurovascular changes
- Examination of recipient site
  - Accurate evaluation of needs
  - Underestimation of ultimate defect
  - Related preexisting neurovascular changes
  - Preexisting physical limitations
- Examination of donor sites
  - Amount and quality of tissues available
  - Vascular examination
- Angiogram/CT/MRA if indicated

Physical examination of potential donor sites can sometimes yield equivocal findings, with absent pulses or old scars, and further study might be warranted, with tests such as CT angiography, MRA, or angiography. Underestimation of the recipient site’s needs is also a common cause of postoperative complications. This can occur from poor planning or unanticipated changes in the recipient site defect. For this reason, a preoperative plan is essential, but once in the operating room, some flexibility is beneficial. We strongly recommend that the surgeon not commit early in the reconstructive process to a particular flap before the final size and characteristics of the defect are known. Even the most experienced surgeons have encountered unforeseen problems intraoperatively. Sometimes a second flap or additional surgical procedures are necessary that could have been avoided. Flaps that are too small, too thick, or have an inadequate arc of rotation or inadequate pedicle length are all avoidable with sufficient planning. One of the most common and avoidable postoperative complications is deep vein thrombosis. A plan should be in place for every patient who is having reconstructive surgery. This is especially true in long reconstructive flap cases, where the risk of DVT goes up exponentially and patients should be considered at increased risk. Sequential compression boots are used in all cases, and the addition of anticoagulants should be considered, depending on the particular clinical situation.
INTRAOPERATIVE EXECUTION

Many things are under the surgeon’s control in the operating room that need attention to prevent postoperative complications (see the box below). Fluid resuscitation and temperature are critical, and homeostasis is achievable with attention to detail. The operative surgeon should be personally responsible for preventing pressure-related injury from inadequate padding, excessive retractor use, or inappropriate patient positioning. Reconstructive surgeries can often be lengthy, and anything that can reduce time in the operating room can translate into lower complication rates. As the surgeon develops a routine for certain procedures, it is important to continually look for ways to be more efficient and reduce time in the operating room. Increased operative time means more tissue edema, more bleeding, and more cardiopulmonary issues, and an increased risk of coagulopathy. Furthermore, the risk of stress ulcers, pressure ulcers, and neurapraxia is increased.

Intraoperative Considerations

- Appropriate fluid resuscitation
- Maintenance of normothermia
- DVT prophylaxis
- Hemostasis
- Padding of pressure points
- Avoidance of excessive retractor use
- Minimizing length of surgery
- Accurate assessment of recipient site
- Accurate flap design and performance
- Ensuring that dressings are not tight/compressive

Despite a well-thought-out, appropriate operative plan, you will sometimes encounter unexpected anatomic variations. It is important not to be rigid in your surgical plan but to assess the variation and decide whether a secondary or tertiary flap should be chosen. All too often a good surgeon will perform a good operation, yet end up with an inadequate result because of an unrecognized anatomic variation. It is important to inspect not only the reconstructive flaps but also the recipient bed for adequacy for reconstruction. Vascularity can be evaluated by clinical examination or by imaging techniques such as laser angiography to help determine whether further debridement is required or other maneuvers are necessary to provide the best chance for successful reconstruction. If the surgeon encounters potential ischemia or venous congestion of a reconstructive flap or recipient site tissues, the time to react is in the operating room. Options include returning the pedicled flap back to its donor site and evaluating it for pedicle compression, kinking, or torsion; microscopically evaluating the vascular anastomoses and the lay of the pedicle for compression, kinking, or thrombosis; performing additional inflow or outflow procedures if possible; delaying the reconstructive flap, with inset at a later time; and debridding ischemic or congested tissues before they can cause a dehiscence, infection, or flap necrosis. The enemy of all reconstructive surgery is tension. Tension on closure is ischemic in nature and can predispose tissue to breakdown. Tension in closure can cause compression on the vascular pedicle, especially as the reconstructive flap and surrounding tissues swell postoperatively. Tension on a microvascular anastomosis or pedicle will predispose to thrombosis. Every effort should be made to reduce tension and to anticipate postoperative tension by changes in swelling, body position, or postoperative dressing. In mobile areas such as the extremities or the head and neck, tension should be checked intraoperatively in positions of movement to ensure that
postoperatively a change in position will not create a problem. If tension is unavoidable when closing skin incisions, maneuvers such as support with acellular dermal matrix (ADM) or secondary closure should be considered. Many a situation has been salvaged by leaving the wounds open and performing dressing changes for 48 hours, allowing borderline tissues a chance to recover. Closing the donor or recipient site by skin grafting is another alternative, with the option of coming back secondarily to excise the graft, if desired.

There are certain errors of planning that are specific to microsurgery. Identification of trauma to the vasculature of the donor flap or the recipient vessels is crucial. The concept of zone of injury, popularized in cases of trauma, extends to all surgical procedures. Injured vessels from any cause, even iatrogenic, are predisposed to thrombosis. Size and mismatch between vessels can also predispose to thrombosis and flap failure. The surgeon must feel comfortable evaluating free flaps for arterial inflow and venous egress, the discussion of which is beyond the scope of this text.

In both pedicle and free flap reconstruction, the use of drains is important for prevention of compression of the vascular pedicle by seroma or hematoma. Although drains do not prevent these complications, they can buy time and prevent compression while the complication is being managed.

The final and sometimes most important part of any reconstructive procedure is the placement of appropriate splints and dressings and proper patient positioning. Constricting dressings, inadequate splinting, and poor positioning of the patient can place inappropriate tension or pressure on the reconstructive tissues and lead to postoperative complications. When leaving the operating room, the patient should be warm, comfortable, and well hydrated. A clearly defined plan for dressings, use of splints, postoperative positioning, and postoperative activity should be confirmed and communicated to everyone caring for the patient postoperatively.

**POSTOPERATIVE FACTORS**

Once the surgical procedure has been successfully performed, the surgeon must be vigilant in postoperative management of the patient to prevent the common problems that are seen in reconstructive procedures (see the box below). The concerns regarding positioning, movements in the area of surgery, and avoidance of pressure on the flaps is carried forward in the postoperative period. Attention to metabolic homeostasis, fluid balance, pulmonary toilet, stress gastritis prophylaxis, and DVT prophylaxis are also critical in combating known and common problems relating to surgery.

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**Postoperative Considerations**

- Fluid balance and maintenance of urine output
- Normothermia
- Pain control
- Pulmonary toilet
- Avoidance of pressure on reconstruction site
- Avoidance of excessive movements
- Flap monitoring
- Appropriate dressings/splints
- Early treatment of infection
- Aggressive treatment of hematoma and seroma
- DVT prophylaxis
- Stress ulcer prophylaxis
One area that is specific to reconstructive flap surgery is postoperative monitoring of
the patient's tissues. Both pedicle flaps and free tissue transfers need vigilant nursing care to
avoid flap loss and dehiscence. In pedicle flaps, this relates primarily to avoiding hematomas
and seromas at the recipient and pedicle sites. Prevention of trauma to the reconstructed
area, both when the patient is in bed and during transfers out of bed, is critical. Prolonged
pressure on a reconstructive flap or vascular pedicle by improper positioning can also cause
partial and total flap failure. Monitoring of free tissue transfers is more critical in the early
postoperative period, because an arterial or venous thrombosis must be identified imme-
diately so that salvage is possible. Free tissue transfers should be monitored by experienced
staff, and a standardized monitoring plan should be in place.

Lengthy reconstructive procedures may be complicated by infection. General surgical
principles apply, and areas of suspected infection should be managed aggressively. When
infection or abscess is suspected near a vascular pedicle, the area should be explored immedi-
ately, washed out, and drained widely to prevent the risk of vascular thrombosis. Appropriate
perioperative antibiotics should be used for such long procedures, and active infections should
be treated with antibiotics directed by culture-specific data. Any contaminated foreign
body should be removed. Negative-pressure wound therapy (NPWT) has been extremely
helpful in the management of postoperative problems; it acts as an open dressing while
maintaining moisture in the wound, minimizing edema, and preventing the spreading or
separation of the surrounding tissues. It is an effective bridge to secondary surgery. When
dealing with partial necrosis or a failed flap in a sick patient, the surgeon's decision to go
back to the operating room can be difficult. No one wants to put a patient's life at risk to
reconstruct a defect that is not life threatening. There are some advantages to consider in
not taking the patient back immediately to the operating room. The ischemic tissue acts
as a biologic dressing, encouraging surrounding tissue revascularization or ingrowth. This
principle, called the Crane principle, can sometimes be used to avoid a second flap surgery.
The term has its origin in thinking of the flap as an engineering crane, dropping in tissue
and later removing it, as necessary. If the patient is stable and there are no vital structures
exposed, the surgeon can wait until there is clear wound separation or evidence of infection.
Once there is evidence of eschar separation, the patient can be returned to the operating
room for debridement of all nonviable tissues. It is sometimes possible at that point, with
enough ischemia-mediated tissue ingrowth, to simply perform a skin graft and close the
wound, discarding the flap completely. If this is not possible, sometimes further NPWT
can salvage the situation to a point at which a skin graft is possible. With that said, it is rare
in a stable patient with evidence of a flap-related problem to regret taking the patient back
to the operating room.

If a second flap is required, the same systematic assessment should be performed for
options and solutions to the problem. It is equally important that the patient be mentally
and physically prepared for this second surgery. The surgeon must be honest and open with
the patient about the surgical procedure and its potential complications and be positive and
confident that a solution is at hand.

As stated at the outset, complications are an ever-present part of reconstructive surgery
and cannot be avoided completely. The occurrence of complications relates to more than
just surgical skill, and many of these factors are out of our control. We can reduce our own
complication rates only by studying our patients, facing up to our shortcomings in planning
and execution, and modifying our own practices.
**Bibliography With Key Annotations**


In this study, the effects of procedure type, timing, and other clinical variables on complication rates in mastectomy reconstruction were prospectively evaluated. Using a prospective cohort design, women undergoing first-time, immediate, or delayed breast reconstruction were recruited from 12 centers and 23 plastic surgeons. Data on complications for expander/implant, pedicle transverse rectus abdominis myocutaneous (TRAM) flap, and free TRAM flap procedures were evaluated 2 years after surgery in 326 patients.


Prone positioning carries with it risks associated with neural and vascular compression. Meticulous attention to avoiding compression will protect against the risks associated with improper positioning, particularly for plastic surgeons.


The authors reviewed their experience with secondary reconstruction following failed free flaps and presented an algorithm for decision-making.


The authors reported their prospective cohort study examining the effect of preoperative smoking on postoperative pulmonary complications in 410 patients scheduled for noncardiac elective surgery. Current smoking was associated with a nearly sixfold increase in risk for a postoperative pulmonary complication. Reduction in smoking within 1 month of surgery was not associated with a decreased risk of postoperative pulmonary complications.


The authors presented a prospective, controlled study that evaluated the effects on coagulation function of active patient warming during elective plastic surgery.


This study evaluated the safety and thus the efficacy of microvascular free tissue transfer in the elderly patient population. Free flaps for different types of reconstructions were analyzed to verify whether free tissue transfer is feasible in the elderly. The authors performed 102 free flaps in 94 patients 70 years of age or older (range 70 to 87 years). The study found that neither operation time nor age was predictive of postoperative complications. Microvascular free tissue transfer is a safe and reliable option in the elderly population. The success rate of free flaps is not different from that for other age groups. The rate of postoperative medical complications was 31% (29 of 94 patients); most complications were in American Society of Anesthesiologists class III and IV patients.


Conventional free flap monitoring techniques (clinical observation, hand-held Doppler ultrasonography, surface temperature probes, and pinprick testing) are proven methods for monitoring free flaps with an external component. Buried free flaps lack an external component; thus, conventional monitoring is limited to hand-held Doppler ultrasonography. Free flap success is enhanced by the rapid identification and salvage of failing flaps. The purpose of this study was to compare the salvage rate and
final outcomes of buried versus nonburied flaps monitored by conventional techniques. The authors retrospectively reviewed 750 free flaps performed for reconstruction of oncologic surgical defects. There were 673 nonburied flaps and 77 buried flaps. All flaps were monitored by using conventional techniques. Both buried and nonburied flaps were used for head and neck and extremity reconstruction. Only nonburied flaps were used for trunk and breast reconstruction. Buried flap donor sites included jejunum (50), fibula (16), forearm (8), rectus abdominis (2), and temporalis fascia (1). Overall flap loss for 750 free flaps was 2.3%. Conventional monitoring of nonburied free flaps was highly effective in this series. These techniques have contributed to rapid identification of failing flaps and subsequent salvage in most cases. As such, conventional monitoring has led to an overall free flap success rate commensurate with current standards. In contrast, conventional monitoring of buried free flaps has not been reliable. Failing buried flaps were identified late and found to be unsalvageable at reexploration. Thus, the overall free flap success rate was significantly lower for buried free flaps. To enhance earlier identification of flap compromise in buried free flaps, alternative monitoring techniques such as implantable Doppler probes or exteriorization of flap segments are recommended.


The authors performed a study of 647 diabetic patients who underwent major noncardiac surgery. The study patients were predominantly nonblack men with a median age of 71 years. Primary outcomes were infectious complications, including pneumonia, wound infection, urinary tract infection, or sepsis. An HbA(1c) level of less than 7% was significantly associated with decreased infectious complications with an adjusted odds ratio of 2.13 (95% confidence interval; 1.23-3.70) and a p value of 0.007. Good preoperative glycemic control (HbA[1c]) levels (less than 7%) is associated with a decrease in infectious complications across a variety of surgical procedures.


Perioperative nurses involved in the intraoperative care of obese patients are faced with numerous issues and challenges. As a growing number of these patients present for medical care, nurses must consider the special positioning needs for surgery and the equipment needed to promote the safest environment for these patients.


The authors conducted a randomized, controlled trial to assess the relationship between body temperature and cardiac morbidity during the perioperative period. They compared routine thermal care (hypothermic group) to additional supplemental warming care (normothermic group) in operating rooms and the surgical intensive care unit at an academic medical center. The outcome measure was the relative risk of a morbid cardiac event (unstable angina/ischemia, cardiac arrest, or myocardial infarction) according to thermal treatment. Cardiac outcomes were assessed in a double-blind fashion. The mean core temperature after surgery was lower in the hypothermic group (35.4 ± 0.1°C) than in the normothermic group (36.7 ± 0.1°C) and remained lower during the early postoperative period. Perioperative morbid cardiac events occurred less frequently in the normothermic group than in the hypothermic group (1.4% versus 6.3%). Hypothermia was an independent predictor of morbid cardiac events by multivariate analysis (relative risk 2.2; 95% confidence interval; 1.1-4.7), indicating a 55% reduction in risk when normothermia was maintained. Postoperative ventricular tachycardia also occurred less frequently in the normothermic group than in the hypothermic group (2.4% versus 7.9%).


The reported success rate of microvascular free flap reconstruction ranges from 95% to 97%. However, when complications occur, they must be identified early and managed efficiently, because there is a narrow window of opportunity to salvage a potentially failing flap. Complications of microvascular
free tissue transfer may occur at the recipient site or at the donor site. Complications occurring at the recipient site are largely a result of vessel thrombosis, whereas complications occurring at the donor site may result from many causes, ranging from infection to those related to the harvesting of the flap. Irrespective of the site of the complication, it is essential that complications be recognized and addressed early in their course to prevent or minimize devastating consequences.


To assess cardiac risk in noncardiac surgery, 1001 patients over 40 years of age who were undergoing major operative procedures were examined preoperatively, observed through surgery, studied with at least one postoperative electrocardiogram, and followed until hospital discharge or death. Documented postoperative myocardial infarction occurred in only 18 patients; although most of these patients had some preexisting heart disease, there were few preoperative factors that were statistically correlated with postoperative infarction. Postoperative pulmonary edema was strongly correlated with preoperative heart failure, but 21 of the 36 patients who developed pulmonary edema did not have any prior history of heart failure.


A review of systemic anticoagulant use in 517 free flap procedures was performed to determine the associated risk of hematoma formation. A cause-and-effect relationship between the use of anticoagulants and flap loss or prevention of thrombosis could not be established. The authors concluded that the use of low-dose heparin does not increase significantly the risk of hematoma or intraoperative bleeding.


A series of 990 consecutive free flaps was reviewed to determine how often pedicle thrombosis occurred, when it occurred, and if the timing of thrombosis detection had any relationship to the probability of flap salvage. The authors concluded that arterial monitoring is most critical immediately after surgery. Beginning on the second postoperative day, venous monitoring becomes progressively more important to flap success. The cost-effectiveness of postoperative monitoring of free flaps is greatest during the first 2 days, after which it decreases significantly.


One hundred eighty-eight consecutive patients who underwent reconstructive head and neck surgery were included in this retrospective study. Information on preoperative smoking habits was obtained from the patients’ medical records. Smokers were defined as having smoked within 7 days before surgery. Late, intermediate, and early quitters were defined as patients whose duration of abstinence from smoking was 8 to 21, 22 to 42, and 43 days or longer before the operation, respectively. Patients who required postoperative debridement, resuture, or reconstruction of their flap before hospital discharge were defined as having had impaired wound healing. The incidences of impaired wound healing among the late, intermediate, and early quitters and nonsmokers were 67.6%, 55.0%, 59.1%, and 47.5%, respectively, and the incidence of impaired wound healing was significantly lower among the intermediate quitters, early quitters, and nonsmokers than among the smokers (85.7%). Preoperative smoking abstinence of longer than 3 weeks reduces the incidence of impaired wound healing among patients who have undergone reconstructive head and neck surgery.


Mild perioperative hypothermia, which is common during major surgery, may promote surgical wound infection by triggering thermoregulatory vasoconstriction, which decreases subcutaneous oxygen tension. Hypothermia itself may delay healing and predispose patients to wound infections. Maintaining
normothermia intraoperatively is likely to decrease the incidence of infectious complications in patients undergoing colorectal resection and to shorten their hospitalizations.


The authors conducted a study to assess the effect of smoking a single cigarette on cutaneous blood flow in habitual smokers as well as in nonsmokers. A laser Doppler flowmeter was used to measure cutaneous microcirculation. Flowmetric data were recorded before smoking, inhaling from an unlighted cigarette, during cigarette smoking, and 2 and 5 minutes after smoking. Results showed that smoking a single cigarette acts on the cutaneous microcirculation, reducing blood flow in both groups of subjects (38.1% reduction in smokers and 28.1% reduction in nonsmokers). Interestingly, the recovery phase was faster in nonsmoker subjects than in smokers; in fact, recovery is complete 2 and 5 minutes after cigarette smoking in nonsmokers and in smokers, respectively. Smoking a single cigarette decreases the cutaneous blood flow in habitual smokers as well as in nonsmokers. Moreover, the slower recovery phase of smokers suggests that their microcirculation becomes inured to smoke.


To examine the efficacy of respiratory physiotherapy for prevention of pulmonary complications after abdominal surgery, the authors searched in databases and bibliographies for articles in all languages through November 2005. Randomized trials were included if they investigated prophylactic respiratory physiotherapy and pulmonary outcomes and if the follow-up was at least 2 days. Efficacy data were expressed as risk differences and number needed to treat, with 95% confidence intervals (CIs). There were only a few trials that supported the usefulness of prophylactic respiratory physiotherapy.

The routine use of respiratory physiotherapy after abdominal surgery does not seem to be justified.


This study assessed the risk for complications in patients who chronically smoke but who have quit in the perioperative period of an elective free tissue transfer, compared with patients who do not smoke. The study's findings suggest that cigarette smokers are at increased risk for complications, not at the site of the anastomosis in free tissue transfer, but rather at the flap's interface with the wound or overlying skin graft.


Free tissue transfers have become the preferred surgical technique to treat complex reconstructive defects. Because these procedures typically require longer operative times and recovery periods, the applicability of free flap reconstruction in the elderly continues to require ongoing review. The authors performed a retrospective analysis of 100 patients aged 65 years and older who underwent free tissue transfers to determine preoperative and intraoperative predictors of surgical complications, medical complications, and reconstructive failures. One hundred four flaps were transferred in these 100 patients. The overall flap success rate was 97%, and the overall reconstructive success rate was 92%. There were 6 additional reconstructive failures related to flap loss, all of which occurred more than 1 month after surgery. Patients with a higher ASA designation experienced more medical complications but not surgical complications. Increased operative time resulted in more surgical complications. All 8 cases of reconstructive failure occurred in patients undergoing limb salvage surgery in the setting of peripheral vascular disease.


The authors reviewed the literature on preoperative pulmonary risk stratification before noncardiothoracic surgery. They included English-language studies that reported the effect of patient- and procedure-related risk factors and laboratory predictors on postoperative pulmonary complication rates after noncardiothoracic surgery and that met predefined inclusion criteria. For certain risk factors and laboratory predictors, the literature provides only unadjusted estimates of risk. Prescreening, variable selection algorithms, and publication bias limited reporting of risk factors among studies using multivariable analysis. Selected clinical and laboratory factors allow risk stratification for postoperative pulmonary complications after noncardiothoracic surgery.


The authors studied 78 healthy subjects (48 smokers and 30 who had never smoke) and followed them for 15 weeks. In smokers, the wound infection rate was 12% (11 of 93 wounds), compared with 2% (1 of 48 wounds) in individuals who had never smoked. Wound infections were significantly fewer in abstinent smokers compared with continuous smokers 4, 8, and 12 weeks after randomization. No difference between the use of the transdermal nicotine patch and placebo was found.


The detrimental effects of smoking on pedicled and free flap reconstruction are well documented. The purpose of this study was to examine the effect of smoking on the flap, donor site, and other individual and multiple complications in pedicled transverse rectus abdominis myocutaneous (TRAM) flap breast reconstruction. A retrospective review was carried out of 224 pedicled TRAM flaps in 200 patients over a 10-year period. Three subgroups of patients were identified: active smokers, former smokers (defined as patients who had stopped smoking at least 4 weeks before reconstruction), and nonsmokers (patients with no history of smoking). Active smokers made up 15.5% of the study population; former smokers and nonsmokers made up 17.5% and 67%, respectively. There were no statistically significant differences in age, weight, radiation/chemotherapy history, distribution of flap pedicle types, timing of reconstruction, or percentage of delay procedures performed among the smoking subgroups. Logistic regression analysis was used to identify significant risk factors and determine their odds ratios. This identified active smoking as a statistically significant risk factor for developing multiple flap complications and TRAM infection, while former smoking was a risk factor for multiple flap complications and TRAM delayed wound healing. Thus pedicled TRAM flap breast reconstruction should be considered contraindicated in active and former smokers, unless the patient has stopped smoking for more than 4 weeks before surgery.


Although obese patients are thought to be susceptible to postoperative pulmonary complications, there are only limited data on the relationship between obesity and lung volumes after surgery. The authors studied how surgery and obesity affect lung volumes measured by spirometry. Considering patients according to BMI (less than 25, 25 to 30, and greater than 30), VC decreased after surgery by 12%, 24% and 40%, respectively.


The authors systematically identified and compared 12 protocols and then applied the protocols to generate insulin recommendations for the management of patients with hyperglycemia. The lack of consensus in the delivery of intravenous insulin infusions is reflected in the wide variability of practice noted in this survey. This mandates close attention to the choice of a protocol. One protocol may not suffice for all patients.

Thrombolytic agents have been demonstrated to improve free flap salvage in animal models. However, clinical evidence regarding their efficacy has been scant. The authors reviewed their experience with flap salvage using thrombolytic therapy in 1733 free flaps.


Plastic surgeons have generally been reluctant to use antithrombotic agents because of the increased risk of bruising or hematoma and the possible need for blood transfusion. However, numerous studies have found little or no increase in the frequency of clinically important bleeding associated with their use. Some plastic surgeons now routinely use chemoprophylaxis in patients undergoing abdominoplasty, combined procedures, or procedures lasting more than 4 hours. The authors also recommend postoperative chemoprophylaxis in circumferential body contouring, thighplasty, surgery requiring open space dissection, transverse rectus abdominus muscle (TRAM) procedures, and surgical procedures likely to contribute to venous stasis or compression. It is impractical and expensive to screen every patient for asymptomatic DVT. A patient history focusing specifically on VTE risk factors should be performed within a few weeks of surgery. Patient education should include information about the symptoms of DVT and PE (including the fact that most patients with VTE are asymptomatic) and a full explanation of the risks and benefits of anticoagulant prophylaxis.


Although inadvertent perioperative hypothermia has received serious attention in many surgical specialties, few discussions of hypothermia have been published in the plastic surgery literature. This article reviewed the physiology of thermoregulation, described how both general and regional anesthesia alter the normal thermoregulatory mechanisms, indicated risk factors particularly associated with hypothermia, and discussed the most effective current methods for maintaining normothermia.
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Part II

Regional Flaps: Anatomy and Basic Techniques

Head and Neck
Anterior Thorax
Posterior Trunk
Upper Extremity
Hand
Abdomen
Abdominal Viscera
Thigh
Leg
Foot
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Chapter 5

Head and Neck

The head and neck present unique challenges in reconstruction. It is one area in which an understanding of three-dimensional anatomy is essential to planning and execution of a successful result. In no other region of the body is so much going on in such a small space. The surgeon must consider such issues as airway maintenance, speech, mastication, swallowing, vision, and facial expression. Reconstruction can affect each of these functions negatively, impinging on the patient’s quality of life. The consequences of failure can be devastating in terms of form and function. In no other part of the body is it more critical to replace like with like—to replace what has been taken away with as exact a copy as possible. As if that weren’t enough, it has to look good: aesthetic outcomes are vital, since there is no way to hide what the plastic surgeon has reconstructed. It is the one area of the body where a beautiful reconstruction is one that should not be immediately apparent to others.

Paramedian Forehead Flap
Scalp Flap
Nasolabial Flap
Temporoparietal Fascia Flap
Temporalis Flap
Masseter Flap
Orbicularis Oris Flap
Tongue Flap
Submental Flap
Facial Artery Myomucosal (FAMM) Flap
ANATOMIC LANDMARKS

Landmarks  Central forehead.
Size  3 cm wide with primary closure; 8 × 6 cm with skin grafting of donor site; larger flaps with delay procedure or tissue expansion.
Composition  Skin with inclusion of frontalis, corrugator, and procerus muscles in its base.
Flap Type  Fasciocutaneous, type B.
Dominant Pedicle  Supratrochlear artery.
Minor Pedicle  Supraorbital artery.
Nerve Supply  Supratrochlear.
Section 5A

HEAD AND NECK

Paramedian Forehead Flap

CLINICAL APPLICATIONS

Regional Use
- Cheek
- Eyelid
- Nose

Specialized Use
- Nose
ANATOMY OF THE PARAMEDIAN FOREHEAD FLAP

A

Vascular supply

Supraorbital artery
Supratrochlear artery
Frontalis muscle
Corrugator muscle
Procerus muscle

B

Relationship of vascular pedicles to skull

Supraorbital artery
Supratrochlear artery
Ophthalmic artery

C

Neural anatomy of forehead

Supraorbital nerve
Supratrochlear nerve

Fig. 5A-1

Dominant pedicle: Supratrochlear artery
Minor pedicle: Supraorbital artery
ANATOMY

Landmarks  This flap uses the forehead tissues for local reconstruction of the upper face. The redundant blood supply in this area allows great flexibility in flap design, using a small portion of the central forehead, or potentially the entire forehead.

Composition  Fasciocutaneous; this is a resurfacing flap. Although the base of the flap will contain portions of the frontalis, corrugator, and procerus muscles, it provides little muscle for reconstruction. The muscles function merely as carriers of the supplying blood vessels.

Size  3 cm width can be closed primarily; an $8 \times 6$ cm flap can be reliably taken without delay. Larger flaps can be taken with delay procedures, including tissue expansion.

Arterial Anatomy

Dominant Pedicle  Supratrochlear artery

Regional Source  Terminal branch of the ophthalmic artery.
Length  3 cm.
Diameter  1 mm.
Location  Exits the orbit superior to the medial canthal ligament, passes through the orbital septum, and enters the glabellar region 2 cm from the midline. It then courses cephalad beneath the frontalis muscle.

Minor Pedicle  Supraorbital artery

Regional Source  Ophthalmic artery.
Length  4 cm.
Diameter  1 mm.
Location  Exits the supraorbital notch, or foramen, approximately 3 cm from the midline in the midpupillary axis, then courses beneath the frontalis muscle.

Venous Anatomy

Accompanying venae comitantes to the supratrochlear and supraorbital vessels.

Nerve Supply

Sensory  Supratrochlear and supraorbital nerves.
VASCULAR ANATOMY OF THE PARAMEDIAN FOREHEAD FLAP

Fig. 5A-2

Dominant pedicle: Supratrochlear artery (D)
Minor pedicle: Supraorbital artery (m)
**FLAP HARVEST**

**Design and Markings**

The middle third of the forehead, with some extension laterally (6 cm wide), can survive without delay procedures based on the dominant vascular pedicle. The height of the flap will depend on the height of the forehead and the desire to carry hair-bearing scalp with the reconstruction; 7 to 8 cm of height without including hair is common. The orientation of the flap can be made more oblique to carry more hairless skin for reconstruction. The narrower the flap base, the easier the rotation of the flap will be. A minimum width of 1.5 cm, including the supratrochlear vessels, is required for flap viability.

![Vertical flap design](image1)

![Oblique flap design](image2)

*Fig. 5A-3*

Accurate measurement of the recipient site will help guide placement of the incisions for the reconstruction. A 1:1 template design should be transposed to the forehead. Simulation of the pedicle arc and reach with a sponge will help determine the adequacy of the pedicle length to reach the reconstructive site.

Doppler examination of the supratrochlear vessels is recommended to ensure their inclusion in the flap, guaranteeing an axial flap for best perfusion.

**Patient Positioning**

The patient is placed in a supine position. If the hair is to be shaved as part of the procedure, it is important to take note of the hairline so that inclusion of hair-bearing skin is intentional and not accidental.
GUIDE TO FLAP DISSECTION
Once the flap is designed and the location of the supratrochlear vessels is confirmed, incisions can be made throughout, down to the periosteum. In cases of nasal reconstruction in which inclusion of the frontalis muscle is not required, the distal and superiormost portion of the flap can be elevated in a subcutaneous plane for approximately 20% of its length. The subdermal plexus is spared.

At this point, the plane is then deepened below the frontalis muscle. The flap is elevated in a supraperiosteal plane. At the glabellar region, within 1 cm of the orbital rim, the plane is deepened to a subperiosteal plane. A Freer elevator is then used to elevate this window of periosteum off the bone in the area of the radix, protecting the pedicle. At this level the corrugator muscle is encountered, and the supratrochlear vessels are intimately associated with it. This area is best divided with bipolar cautery, again taking care to avoid injury to the supratrochlear vessels. These vessels may not be visualized during the procedure, but their position can be easily confirmed with a Doppler probe.
The base of the flap is extended as needed to reach the reconstructive site; it commonly divides the eyebrow and runs into the upper inner aspect of the orbit. This occurs frequently in nasal reconstruction, and the eyebrow will later be returned to its normal position during division and inset of the flap.

**FLAP VARIANTS**

- Tissue expansion–assisted flap
- Delay flap
Tissue Expansion–Assisted Flap
For larger tissue requirements, a tissue expander can be used to expand the available tissues for reconstruction. Tissue expanders are used in one of two ways. First, the expander can be placed in the area desired for reconstruction. Expanding the central forehead can provide a larger flap for reconstruction and aid in donor site closure. There is some evidence that these expanded flaps can develop secondary contracture that leads to distortion, especially in nasal reconstruction, but this is controversial. The second, more reliable technique is to place tissue expanders in areas laterally for donor site closure, leaving the central portion of the forehead unexpanded to be used for reconstruction. The expanded lateral forehead on each side is used for primary closure so that a larger primary flap can be harvested. To use the expander technique, one would have to have the elective time for expansion. In some cases, a preliminary skin graft for wound closure can be performed to extend the time needed.

Delay Flap Procedure
If a larger flap is desired or if the flap procedure is being performed in a patient who has poor vascularity or is a smoker, a delay of transfer of the flap may be warranted. A delay procedure can be planned, or it can be performed based on intraoperative findings. If a primary transfer is planned and the surgeon is unhappy with the appearance of the flap after it has been elevated, returning the flap to its bed will give the flap its best chance of survival, because the position of the flap will afford the best venous drainage, and the lack of rotation at the base will limit potential interference with blood flow from kinking and postoperative edema. If the flap could not survive by simply being returned to its donor site, it would not have survived in its reconstructive site. More commonly, a delay can be planned in patients who are at high risk for the use of larger flap sizes. In general, the design of the flap will include the supratrochlear vessel or vessels at its base, as confirmed by Doppler examination. Because the plane of dissection is an areolar plane, little blood supply will be provided by the undersurface of the flap. Therefore it is advisable to not completely incise
the flap, leaving the areas at higher risk intact with the surrounding tissue to provide extra blood supply and extra drainage that would otherwise compromise the flap. These small areas of attachment allow axialization of the blood supply so that in 2 weeks, these areas can be divided and the flap will survive.

Another way to use forehead tissues with the delay phenomenon is to plan the flap on the more lateral superficial temporal vessels. Blood supply based on these vessels is unreliable across the midline, so a surgical delay is warranted. In these cases, skin grafting is required for donor site closure, and the aesthetic forehead subunit should be respected for best cosmesis.
ARC OF ROTATION

Standard Flap
The flap will cover defects that range from the level of the eyebrow to the lip. Flaps can be rotated either clockwise or counterclockwise based on the recipient site and particular need of the reconstruction.

FLAP TRANSFER
Once the flap is elevated to the level of the orbital rim, it is worth transposing the flap and deciding whether further elevation is needed. After the final degree of flap elevation, the flap can be inset directly without the need for a tunnel to reach the recipient site. In eyebrow, eyelid, and cheek reconstruction, the inset can be direct, without a secondary procedure. For nasal reconstruction, often the flap is transferred, leaving its pedicle exposed, bridging normal skin at the radix and upper nose to reach the more distal part of the nose. Then the exposed base will be grafted or dressed for the intervening delay period.

FLAP INSET
The flap may be directly sutured into the defect. In some cases, a partial inset is recommended, especially when final stitching of the flap causes the skin to blanch because the blood supply is poor. Partial inset with tacking sutures can be performed, and final suturing can be done in the office 48 hours later with the use of a local anesthetic.

DONOR SITE CLOSURE
Direct donor site closure is recommended, when possible. Even for the narrowest of pedicles, wide undermining of the forehead is often required. Scoring of the galea can assist in gaining an extra centimeter or more of advancement to allow primary closure under tension. It is not uncommon, especially near the hairline, to have areas that cannot be closed primarily. Simple dressing changes allow healing by secondary intention, which in most patients can be cosmetically acceptable. The donor site can be closed with a skin graft, especially if the exposed base of the flap is being grafted anyway. This may have cosmetic consequences, and often secondary procedures are required to excise these grafts. Tissue expansion of the forehead can be performed at the initial surgery before flap transfer, or as a delayed procedure after unacceptable scarring has occurred from secondary healing or skin grafting of the donor site. The timing of tissue expansion is at the surgeon’s discretion.
CLINICAL APPLICATIONS
This patient shows the use of a forehead flap in cheek reconstruction after radiation therapy and surgical excision of an angiosarcoma.

Fig. 5A-8 A, Residual angiosarcoma of the left cheek. B-D, The reconstruction was designed using a forehead flap with a template guide, cheek advancement flap, and upper eyelid flap. E, The left cheek defect is shown after surgical excision. F and G, The immediate and long-term postoperative results are shown. (Case courtesy Julian J. Pribaz, MD.)
This 64-year-old man was seen after resection of a basal cell carcinoma of the nose in which the full thickness of the left ala was excised. The patient required reconstruction of all layers, including lining, support, and cover.

Fig. 5A-9  
A, The preoperative defect and the planned forehead flap. The dots denote Doppler points of the supratrochlear vessels.  
B, Lateral view of the defect after lining flaps and cartilage grafts placed. 
C, Worm’s-eye view showing the degree of tissue loss and the cartilage necessary to buttress the reconstruction. 
D, Flap after inset with primary closure of the donor site. 
E, AP view of the patient at 6 month follow up. The patient was satisfied with the result and refused any revisional surgery. 
F, Oblique view. 
G, Lateral view. (Case supplied by MRZ.)
This 55-year-old man had undergone a Mohs resection of a basal cell carcinoma of the nose. This defect had bony support but needed some lining and soft tissue cover.

Fig. 5A-10  A, The preoperative defect. B, The forehead flap is elevated and skin grafts are used to laminate the flap where lining is needed. C, The flap is inset and primary closure of the donor site has been accomplished. D, Flap at 2 weeks postoperatively, ready for division and inset. E, AP view, 8 months postoperatively. F, Lateral view. (Case supplied by MRZ.)
This is an example of how to delay a forehead flap. The 67-year-old woman had a previous midline scar in the forehead and was an active smoker. Because of the midline scar, tissue harvest was limited to the right side of the forehead.

Fig. 5A-11  
A, The nasal defect has been skin grafted as the plan involves delaying the closure for two weeks. The flap design shows that the most ischemia prone lateral tissues has a maintained skin bridge to vascularize the area until the flap becomes more robust. B, Lateral view of the skin bridge. This bridge was sutured closed in the office under local anesthesia at one week. C, At 2 weeks postoperatively, the flap is ready for transfer, without evidence of ischemia, and is supplied only by the supratrochlear vessels. (Case supplied by MRZ.)
This 79-year-old woman had two Mohs defects, one on the dorsum of the nose and the other on the left side of the forehead. She had adequate support but needed some midvault lining.

Fig. 5A-12  A, The flap design has been made more oblique to allow primary closure of the forehead Mohs defect after the flap is elevated. Also, the remaining glabellar skin will be used as a turnover flap to line the defect. The donor and recipient sites will be connected. B, Turndown of the glabellar flap for lining. C, Forehead flap directly transposed and inset with a small glabellar dog-ear left in place. The donor site is closed primarily with the Mohs defect. D and E, Oblique views of the result at 4 months postoperatively. No revision of the dog-ear was required. (Case supplied by MRZ.)
This 46-year-old man had a Mohs resection of a skin cancer of the medial canthal area. The forehead flap can be a good choice for resurfacing needs around the orbit.

![A, Defect with proposed forehead flap. B, AP view of the flap inset. C, Oblique view. Since the flap design abutted the defect, a direct transposition was possible. Care should be taken to avoid ischemia and delay any debulking procedures to a later date. (Case supplied by MRZ.)](image)

This woman in her mid-forties had a Mohs defect within most of the left ala after excision of a basal cell carcinoma. Although the defect is similar to the one in the older patient shown in Fig. 5C-15, it was repaired with a two-stage subunit forehead flap and primary cartilage graft, rather than a two-stage subunit nasolabial flap. The nasolabial fold in younger patients has less available excess and often a less distinct nasolabial crease from which to harvest donor materials; therefore a forehead flap is often preferred when resurfacing the nose to avoid the distortion of midface donor landmarks, which frequently occurs after harvesting tissue from the nasolabial fold. In almost all circumstances, forehead donor deformities are less apparent than nasolabial flap deformities.

![A and B, The defect of the ala was closed as a subunit, with a right paramedian forehead flap. The result is excellent. The fine vertical forehead donor scar does not distort adjacent tissues, nor draw attention to the nasal reconstruction. (Case courtesy Frederick J. Menick, MD.)](image)
Pearls and Pitfalls

- Although the flap can survive without identifying the supratrochlear or supraorbital vessels in its base, one should avoid injury to these vessels and maintain them for best perfusion.
- The surgeon should avoid skeletonization of these vessels and the desire to see them before transfer. In periorbital reconstructions, tunneling the flap may cause congestion and ischemia. It is best to connect the recipient and donor sites and directly rotate the flap.
- Aggressive thinning of the flap in its area of redundancy at its rotation point should be avoided—this is the blood supply to the flap. This can be done more safely at a later time.
- Doppler ultrasound is used to identify the supratrochlear vessels and ensure that they are within the flap. If the supratrochlear vessels cannot be followed for a few centimeters, delay of the flap should be considered.
- More oblique flap designs will require more random blood supply and delay should be considered.
- These valuable tissues should not be wasted on building the substructure of nasal or orbital reconstruction. The forehead flap should be the last finishing piece to resurface the reconstruction, because it has the best texture and color match of all reconstructive flaps of the face. This is especially true in nasal reconstruction, when smaller flaps may suffice, and the forehead flap may be required at a later time.

EXPERT COMMENTARY

Michael R. Zenn

Indications
The forehead flap remains the gold standard for color match and tissue consistency in facial reconstruction. It is the most commonly used flap for nasal reconstruction but can be used creatively for reconstruction in the periorbital area as well.

Advantages and Limitations
A central forehead flap can be elevated without identification of the blood vessels because of the robust blood supply of the supratrochlear, supraorbital, angular, infratrochlear, and dorsal nasal vessels. However, rotation of the pedicle flap, reach of the flap, and prevention of kinking of the base of the flap will all benefit from as narrow a base as possible. By using a Doppler device to identify the supratrochlear vessels, this can be accomplished. This area of the face, especially for a nasal reconstruction, should be considered prime real estate and should not be squandered when reconstructing significant defects of the face or complex defects of the nose.

The forehead tissues should be the last used in reconstruction for final resurfacing and a final aesthetic result. Reconstruction of the foundation of the orbit or of the nose should be performed with other flaps and other tissues. Once the forehead has been used, it is possible to reharvest, depending on the previous surgery and previous incisions, although this will be more difficult and will likely require tissue expansion or grafting of the forehead.

Continued
Anatomic Considerations

One should have patience when using the forehead flap for reconstruction, especially with nasal reconstruction. The superior portion of the flap will be the most important part used for reconstruction, but also be the most ischemic portion of the flap. It is often appropriate to take a stepwise approach to preparing tissues for final reconstruction. Often the areas reconstructed on the columella and tip of the nose require as thin a flap as possible. Too much thinning at the initial procedure can cause loss of the flap and loss of the most valuable tissue for reconstruction. I recommend elevating the flap and thinning its distal-most part only to the subcutaneous level, and only for a distance of 1 to 2 cm. One should be able to visualize the axial vessels within the subcutaneous tissues and spare them. At 10 to 14 days, one can return and reelevate the flap, thinning it a second time if thinner tissues are needed, since the flap will have acclimated to its new blood supply and position and will be more reliable and robust. Some may do two or more thinnings before division of the base of the flap and final inset.

Recommendations

Planning

Cosmesis at the donor site is excellent in these median forehead flaps. A vertical design will leave a vertical scar, which ultimately will heal best. Areas of dog-ear superiorly can be extended into the hair-bearing scalp and excised without compromising vascularity. It is not uncommon to have fullness at the glabellar area when performing periorbital reconstruction, from rotation of the pedicle. Fullness of this area is also a common problem after division and inset of the pedicle. When dividing the pedicle and returning tissues to the forehead, it is recommended to aggressively thin the glabellar area, which includes resection of the corrugator muscles in this area. I take more tissue than I anticipate I need to take and have been much more pleased with the resulting donor site. This has also limited the amount of revisions that are required in this area.

In designing the flaps for the recipient site, it is important to make accurate templates as to the need for tissue. The templates should be the exact size of the tissue requirements.

Technique

When reconstructing areas that have healed by secondary intention or skin grafting, one must excise the area of cicatrix or skin graft and allow the tissues to resume their normal position. This will increase the size of the recipient area and allow a more accurate reconstruction. In smokers and patients with poor vascularity, I have a low threshold for delaying the flap, leaving the flap attached distally and training the blood supply to improve the vascularity of the flap. Completion of the delay can be performed in the clinic, with simple suturing of the small bridges to confirm excellent vascularity and complete the delay before the actual surgical date. Timing of the delay may depend on patient vascularity but can safely be performed at 2 weeks. I recommend placing a tourniquet with a simple elastic in the holding area around the pedicle at the glabella. By the time the patient is taken to the operating room, it will be quite clear whether the flap has adequate vascularity or not. If the flap appears to be ischemic or markedly congested, further delay is warranted.
Complications

The main complications relating to use of the paramedian forehead flap involve ischemia, partial flap loss, and scarring of the forehead donor site. If the surgeon upon flap inset finds evidence of ischemia to the tip of the flap, delaying the final inset should be considered. Tacking sutures can be placed to hold the tissue and final closure can be performed 4 to 7 days later in the office under local anesthesia. Although the forehead scar is usually acceptable, there are times when excessive tension or secondary healing leave a less than ideal scar. I generally recommend waiting 4 to 6 months before considering scar revisions in the forehead.

Bibliography With Key Annotations


The first choice for internal mucosal restoration of the nose is a septal mucosal or vestibular local flap. The forehead flap, raised including the galeal layer, is an alternative option for large nasal defects. It can be used in any difficult situation in which septal or vestibular flaps are not adoptable, such as complete loss of the lower third. The authors described the inclusion of the galea in the traditional median forehead flap for nasal lining reconstruction. Thirteen patients treated with a forehead flap including the galea for lower third nasal reconstruction were retrospectively reviewed. No complete flap necrosis occurred. In one case, lining was lost to infection. In two cases, a moderate nostril stenosis was observed as a late complication.


Despite the benefits of the minimally invasive technique, complications may occur, raising doubts about the safety of polymethylmethacrylate as an injectable filler material. The authors reported their treatment of a patient from another institution with necrosis involving full-thickness nasal skin and upper lip after injection of polymethylmethacrylate in the nasolabial folds and nose for augmentation. An expanded median forehead flap was used to reconstruct the nose, and an Abbé flap was used for the upper lip. The flaps and the skin expander allowed reconstruction with correct texture, color, and dimensions, producing a good aesthetic and functional outcome.


A 13-year retrospective review was carried out of all pediatric patients who completed reconstruction for lesions involving at least 25% of the forehead by a single surgeon. All lesions were classified by the percentage of forehead involved and involvement of adjacent subunits. Twenty patients completed reconstruction. A median of six (range 2 to 11) surgical procedures was required, with a median of three (range 1 to 4) expansion procedures. Simultaneous expanders were placed in the scalp (16 patients) and cheek (8 patients). Five patients underwent correction of eyebrow ptosis as a final procedure. Reconstruction involved 25% to 70% of the forehead in 19 patients, 17 of whom were reconstructed with serial forehead expansion and advancement flaps. One patient with a pigmented nevus occupying more than 75% of the forehead received an expanded full-thickness skin graft from the lower abdomen. For all groups, the entire extent of the visible lesion was excised and complete skin coverage achieved.


For the previous 15 years, the authors had used a forehead flap with its pedicle based at or below the medial canthus without any flap loss. This study described the anatomic vascular relationships that allowed this flap design to be successful. Nine fresh-frozen cadaver heads were studied in three groups. Six heads were injected with red latex. In group I, the supraorbital, supratrochlear, and facial arteries of four heads were dissected out under the operating microscope. In group II, using two latex-injected heads, the median forehead flap was elevated in the extended fashion, and the arteries within the flap were dissected. The distal portion of the flap was elevated supraperiosteally, and the proximal portion was elevated subperiosteally. In group III, the arterial systems of three heads were injected with barium solution after the flaps had been elevated. Radiographic assessment was used to demonstrate the vascular pattern within the flap. Group I showed an anastomotic relationship between the supratrochlear and facial arteries and a consistent relationship between the infraorbital and facial arteries. Group II showed that the above-mentioned connections could be protected during the supraperiosteal and subperiosteal flap elevation. This was confirmed by radiographic assessment in group III. The vascular network of the flap was filled through the facial artery via the dorsal nasal and supratrochlear arteries. Within the paranasal and medial canthal region, there is an anastomotic relationship between the supratrochlear, infraorbital, and branches of the facial arteries, and branches from the contralateral side, creating a rich vascular arcade. This allows a median forehead flap to be narrowly based at the level of the medial canthus.


The author reported the largest prospective cadaver study conducted over a 3-year period to investigate the arterial variations of the forehead. The primary goal was to find anatomic support for various previously designed forehead flaps. Thirty cadaver foreheads (60 hemiforeheads) were dissected from deep to superficial to identify arterial variations. The arteries were filled with a latex solution before dissection. The author detailed the findings and concluded that the significance of the central artery and vein favors the median forehead flap as anatomically superior, and the prominent central vein is a constant landmark on which to select the side of the pedicle.


The authors reviewed the charts of their patients from 1995 to 2008 to identify those characteristics and comorbidities that are associated with a higher rate of complications in patients undergoing nasal reconstruction with a forehead flap. They reviewed the charts of 205 patients with a median age of 66. Three preexisting comorbidities were tracked: diabetes, smoking, and vascular disease. Major complications (flap necrosis, nasal obstruction, alar notching) and minor adverse outcomes (partial nasal obstruction, epidermolysis, and alar asymmetry) were recorded. Full-thickness defects were significantly associated with higher incidences of any major complication and had higher odds of flap necrosis and alar notching. Smokers had higher odds of developing flap necrosis. Neither the presence of diabetes, increased age, or vascular disease was significantly associated with higher rates of major complications.


This paper reported on the management of patients with subtotal and total nasal defects with the use of forehead and nasolabial flaps. From 2007 to 2010, 20 patients with total or subtotal nasal defects were observed; 6 defects resulted from trauma and 14 from tumor resection. All were full-thickness defects of the nasal mucosa, skin of the nasal antechamber, cartilage frame, and external nasal skin.
All were appropriate for local flap reconstruction. A median forehead flap was used in 12 cases, a nasolabial flap in six cases, and a combination of these two flaps in two cases. Satisfactory results were achieved in all patients except for one with speech dysfunction. Nasal function was maintained with proper porosity of the nostril. The three-dimensional appearance of the nose was reconstructed with acceptable aesthetic results.


The midline forehead flap is used in the reconstruction of large, deep defects of the medial canthal area and lower eyelid. Drawbacks included a cosmetically unfavorable skin bulge at the nasal bridge and obliteration of the natural medial canthal concavity, both of which required correction in a second stage. The authors adopted a modification of the technique to avoid these drawbacks. They reviewed the medical records and photographs of their patients who underwent the tunneled midline forehead flap procedure to repair medial canthal defects and anterior lamellar repair of eyelid defects. The forehead flap was elevated in the subdermal plane, and the pedicle was deepithelialized and transferred through a subgaleal tunnel from the pivot point of the flap into the primary defect. Nine patients had defects of the medial canthal area, the medial part of the eyelids, or both after surgical removal of malignant tumors. Follow-up ranged from 5 months to 6.1 years (mean 2.1 years; median 11 months). In all cases, flap viability was maintained, the globe was protected, and the concave architecture of the medial canthus was preserved.


Most forehead defects that cannot be closed primarily are reconstructed with laterally based advancement flaps. The author described a combination of a median forehead rotation flap and an advancement lateral U-shaped flap for repair of medium to large defects in paramedian and lateral forehead. Technically the design of the median forehead rotation flap based on supratrochlear vessels was similar to the median forehead transposition flap used to reconstruct large defects of the nasal dorsum. The length and movement of the flap were much smaller in this case. Approximately two thirds of the closure of the defect was achieved by displacing the median forehead flap, whereas the remaining third corresponded to the advancement of the lateral U-shaped flap. These flaps are simple to perform, have minimal complications, and have good cosmetic results. A representative case was presented along with photographs.
ANATOMIC LANDMARKS

**Landmarks**
The scalp encompasses the entire hair-bearing portion of the head and can include non-hair-bearing areas of the postauricular area and forehead.

**Size**
The entire scalp may be elevated. Individual flaps based on designated pedicles may be up to 30 cm in diameter with skin grafting of the donor or tissue expansion.

**Function**
The scalp contains the frontalis and occipitalis muscles responsible for brow elevation and some limited scalp movements. Muscle may be part of flaps designed from the scalp, but the muscles are not functional. The scalp also has a role in temperature regulation.

**Composition**
Fasciocutaneous, type A.

**Dominant Pedicles**
Superficial temporal artery and venae comitantes; occipital artery and venae comitantes.

**Minor Pedicles**
Supratrochlear artery and venae comitantes; supraorbital artery and venae comitantes; posterior auricular artery and venae comitantes.

**Nerve Supply**
*Motor:* Temporal branch of the facial nerve, zygomaticotemporal branch of the maxillary nerve, and the auriculotemporal branch of the mandibular division of the trigeminal nerve. *Sensory:* Supratrochlear, auriculotemporal, postauricular, greater occipital, lesser occipital, great auricular, and third occipital nerves.
Section 5B

HEAD AND NECK

Scalp Flap

CLINICAL APPLICATIONS

Regional Use
  Scalp
  Face

Specialized Use
  Scalp
  Nose
ANATOMY OF THE SCALP FLAP

A
Galea aponeurotica
Superficial temporal artery
Frontalis muscle
Occipitalis muscle
Occipital artery
Occipital nerve
Posterior auricular artery
Temporal nerve
Superficial temporal nerve

Lateral view

B
Galea aponeurotica
Supratrochlear artery
Supraorbital artery
Supraorbital nerve
Supratrochlear nerve

Anteroposterior view

C
Galea aponeurotica
Occipitalis muscle
Occipital artery
Occipital nerve
Posterior auricular artery

Posterior view

Fig. 5B-1

Dominant pedicles: Superficial temporal artery; occipital artery
Minor pedicles: Supratrochlear artery; supraorbital artery; posterior auricular artery
ANATOMY

Landmarks  This specialized area of skin covering the cranium has unique hair-growth characteristics. The blood supply to this area is rich, and areas beyond the hair-bearing area and the retroauricular and forehead areas can also be incorporated into flaps.

Composition  Fasciocutaneous. Specialized hair-bearing skin is unique to this part of the body. Frontalis and occipitalis muscles incorporated in flaps are not functional.

Size  Although the entire flap can be elevated on a single pedicle, flaps on designated pedicles can have a width of up to 30 cm. Primary closure may be possible with expansion; however, back-grafting with a skin graft is often necessary for these large advancements.

Function  Temperature regulation and facial expression.

Arterial Anatomy

Dominant Pedicle  Superficial temporal artery
REGIONAL SOURCE  External carotid artery.
LENGTH  5 cm.
DIAMETER  2.5 cm.
LOCATION  Originates from the external carotid and courses in the preauricular area and over the zygomatic processes of the temporal bone. The pedicle branches into both frontal and parietal branches, which are located superficial to the superficial temporoparietal fascia. Both vessels then course toward the midline of the scalp.

Dominant Pedicle  Occipital artery
REGIONAL SOURCE  External carotid artery.
LENGTH  4 cm.
DIAMETER  2.5 mm.
LOCATION  Passes beneath the sternocleidomastoid and neck musculature. It then passes between trapezius and sternocleidomastoid muscles into the occipitofrontalis muscles 4 cm lateral to the occipital protuberance. The vessel then courses anteriorly.

Minor Pedicle  Supratrochlear artery
REGIONAL SOURCE  Terminal branch of ophthalmic artery.
LENGTH  3 cm.
DIAMETER  1 mm.
LOCATION  Exits the orbit medially as it courses through the corrugator muscles and frontalis muscle cephalad over the epicranium.

Minor Pedicle  Supraorbital artery
REGIONAL SOURCE  Ophthalmic artery.
LENGTH  4 cm.
DIAMETER  1 mm.
LOCATION  Exits through the supraorbital foramen beneath the frontalis muscle and courses cephalad.

Minor Pedicle  Posterior auricular artery
REGIONAL SOURCE  External carotid artery.
LENGTH  3 cm.
DIAMETER  0.5 mm.
LOCATION  Arises in common either with the occipital or the superficial temporal artery.
Venous Anatomy

Named vessels with accompanying venae comitantes.

Nerve Supply

**Motor**
Temporal branch of the facial nerve, zygomaticotemporal branch of the maxillary nerve, and the auriculotemporal branch of the mandibular division of the trigeminal nerve.

**Sensory**
Supratrochlear, auriculotemporal, postauricular, greater occipital, lesser occipital, great auricular, and third occipital nerves.

**Vascular Anatomy of the Scalp Flap**

**Dominant pedicles:** Superficial temporal artery ($D_1$); occipital artery ($D_2$)

**Minor pedicles:** Supratrochlear artery ($m_1$); supraorbital artery ($m_2$)
FLAP HARVEST

Design and Markings
The scalp has the following sources of circulation: the anterior central scalp has the supra-trochlear and supraorbital vessels; the anterior preauricular scalp has the frontal and parietal branches of the superficial temporal artery; the anterior postauricular scalp has the posterior auricular vessels; and the posterior scalp has the occipital vessels. These vessels should be localized with a Doppler probe before scalp flaps are planned and designed. For best perfusion, any flap design should locate one or more of these pedicles within the base of the flap. The actual number of flaps will depend on the clinical situation and the remaining blood supply. Simple single flaps, two-flap, three-flap, and four-flap techniques have been described. Scalp flaps in general do not extend beyond the anterior hairline to preserve the aesthetic subunit of the forehead.

Fig. 5B-3
Patient Positioning

Patient positioning will depend on the area of the defect and the donor site used. In general, the prone position will be most useful for lateral and posterior defects and defects of the vertex. Anterior defects near the hairline are often best addressed with the patient in the supine position. Full exposure of the head is necessary, because scalp mobilization will be performed around the entire scalp, regardless of the size of the defect.
GUIDE TO FLAP DISSECTION

Flaps are incised down through the galea and flaps are quickly elevated in this areolar plane. Expansion of the flaps is performed through the technique of galeal scoring. This is done either with a knife or a Bovie cauterity. With either technique the galea is opened across either the width or length of the flap, depending on the reconstructive need. The galea can be scored every 1 to 2 cm, depending on need. Care must be taken to preserve the vasculature that lies below the galea.

![Diagram of scalp flap dissection](image)

**Fig. 5B-4**

- **A** Flap elevated and scored
- **B** Flap advanced
- **C** Across width to increase length
- **D** Lengthwise to increase width
In cases in which the source blood vessel cannot be found by Doppler ultrasound or where long thin flaps are required for reconstruction, a delay procedure should be considered. A delay would involve incision of the sides of the flap, keeping both the base and the tip of the flap attached. The flap is undermined again in the subgaleal plane, and then the incisions are closed. In 7 days, the distal tip of the flap can be incised, and at 10 to 14 days, the flap is rotated.

**FLAP VARIANTS**

- Three- or four-flap technique
- Temporoparietal flap
- Occipitoparietal (Juri) flap
- Washio flap
- Tissue expander–based flaps

**Three- or Four-Flap Technique**

For a scalp defect, coverage with a two- or three-flap technique is commonly used. This allows expansion of each of the flaps elevated to increase the surface area to cover the defect. These flaps, once scored, can be advanced or rotated into position. Not uncommonly, back-grafting is required to completely close donor sites.
Fig. 5B-5  **A,** Bipedicle flap oriented parallel (1-2) to the defect on the left temporal frontal scalp.  
**B,** Bipedicle flap divided to form two flaps. The flap based on occipital artery (1) will advance to the anterior scalp; the flap based on the parietal branch of the superficial temporal artery (2) will advance to the posterior scalp; the flap based on the contralateral occipital artery (3) will close the donor defect as an advancement flap. **C,** Parallel incisions through the galea at 1 to 2 cm intervals allow flap expansion without interruption of vascular pedicles superficial to galeal layer. **D,** Final closure with flaps inset.
Temporoparietal Flap

These more centrally based flaps are based over the superficial temporal system and are often used for more specialized purposes such as eyebrow and mustache reconstruction. When used for these purposes, these flaps can be elevated as unipedicle flaps for unilateral reconstruction or bipedicle flaps for mustache reconstruction. Because of the length and narrow design of these flaps, a delayed procedure is often recommended for best viability (see Fig. 5B-15).

Fig. 5B-6 The four-flap technique is particularly applicable in a child.
Occipitoparietal (Juri) Flap
This is the most commonly used flap for alopecia surgery and reconstruction of the anterior hairline. Based on the temporal or occipital vessels, the length and width of this flap often requires a delay procedure to carry the entire length of the scalp to reconstruct the entire anterior hairline. Again, both proximal and distal attachments are maintained while the remainder of the flap is incised and elevated and then resutured. The flap may be advanced into position at 10 to 14 days after delay. Often with the Juri flap the remaining scalp can be advanced and closed without skin grafting.

Fig. 5B-7
**Washio Flap**

This flap takes advantage of the non-hair-bearing skin in the mastoid area. Oftentimes no other tissues are available for specific reconstructions such as nasal reconstruction where good color and texture match are critical for a reconstruction. The Washio flap elevates the scalp and carries this portion of non-hair-bearing skin from the postauricular area to the nose. The defect created in the postauricular area is skin grafted while the area of exposed scalp can be dressed during the process of revascularization of the flap. Similar to a forehead flap, the pedicle, which supplies the skin, can be tubed for control of the wound. After 10 to 14 days the flap can be divided and the scalp tissues are returned to the scalp replacing areas of temporary dressing although the postauricular area maintains its skin graft. Use of this flap is limited to situations in which no other locally based flaps are available.

![Flap design with superficial temporal pedicle](image1)

![Flap elevated with arc of rotation to nose](image2)

![Flap inset of nose](image3)

**Fig. 5B-8**
Tissue Expander–Based Flaps
Most commonly tissue expansion can be performed in the scalp to increase the surface area of the specialized hair-bearing tissues. The expansion process itself can often take weeks to months; therefore one must have the time to perform the expansion. Most commonly the defect to be reconstructed is skin grafted or is benign in its nature such that the expansion can be performed first. The general rule of thumb is to place as large a tissue expander as one can fit in any one location and to place as many expanders as possible to completely expand the scalp tissues. Once expansion is complete, flaps may be designed as straight advancement flaps or rotational flaps to move the excess tissue generated into the defect and still allow primary closure (see Figs. 5B-10, 5B-14).

ARC OF ROTATION
One-, Two-, Three-, and Four-Flap Techniques
Galeal scoring of these flaps allows expansion in either length or width necessary to rearrange these flaps for a reconstruction. These flaps generally are advanced or rotated and the arc of rotation will depend on the designed length and the amount of advancement allowed by scoring. Remember, any flap rotation will lose length with rotation. Defects of up to 20 cm in diameter have been closed using these techniques (see Figs. 5B-5, 5B-6, 5B-11).

Temporoparietal Flap
These flaps can safely be designed to midline and rotated safely in a single-stage procedure. When flaps are extended past the midline, a delay procedure is recommended. By dissecting the superficial temporal pedicle down toward the preauricular area, areas of the eyelid and mustache can easily be reached (see Fig. 5B-14).

Occipitoparietal (Juri) Flap
The point of rotation for the Juri flap is at the top of the ear. To reconstruct an entire hairline, the flap length must be measured from this rotation point. Because of the narrow width of these flaps and their long length, a delay is recommended for viability of these flaps. Once delayed, the flap should easily reach across the anterior hairline to the contralateral side.
Washio Flap
Most commonly used for nasal reconstruction, the Washio flap is elevated and easily reaches the area of the nose without galeal scoring (see Figs. 5B-8, 5B-15).

Tissue Expansion
Actual reach of the flaps created by tissue expansion will depend on the amount of expansion. Measurements from the base pedicle up and around the tissue expander will indicate the length of reach from the base of the pedicle to the area of reconstructive need and can guide the surgeon during tissue expansion (see Fig. 5B-13).

FLAP TRANSFER
One-, Two-, Three-, and Four-Flap and Temporoparietal, Occipitoparietal, and Washio Flap Techniques
Once elevated, flaps are transposed or advanced to the defect and secured in the galeal and dermal levels. Burying these pedicles or tunneling them is not recommended, except in eyebrow or mustache reconstruction. If flap transposition from the donor site to the recipient site crosses normal tissue, the flap may be tubed or dressed on its exposed side and temporized while tissue ingrowth occurs. It is usually safe to divide these flaps at 10 to 14 days, depending on the clinical situation and return of the pedicle tissue back to its donor site.

Tissue-Expanded Flaps
One must decide, based on the tissue generated and the need for reconstruction, whether the flap should be advanced as a transposition or pure advancement flap. Again, burying or tunneling the flap is not recommended. It is often possible to split the area crossed by the pedicle tissue to allow a direct one-stage inset. All rotated or transposed flaps may create a dog-ear, which should be left and not revised immediately, because this may compromise blood supply.
Flap Inset

Scalp flaps have a robust blood supply but can be made ischemic by too much tension on closure. Clinical inspection of the flap is important, and if the flap appears white from tension, delayed inset of the flap is recommended. The flap may be temporarily tacked with some tacking sutures and the patient returned to the operating room 48 hours later for final closure. Otherwise, the flap is secured in its new position with both galeal and skin suturing.

Donor Site Closure

All Flap Variants

If flaps are planned for a primary donor site closure, this often can be accomplished once the flap has been rotated or advanced. The remaining defect can be closed by simple galeal scoring and advancement. Often the amount of tissue used for reconstruction dictates that a skin graft will be required at the donor site. This allows a primary wound closure, and the area of alopecia can be addressed at a later time through serial excision or tissue expansion to remove the skin graft, if warranted.
CLINICAL APPLICATIONS
This 63-year-old man underwent resection of a brain tumor after preoperative embolization. Probably as a result of this embolization, the scalp flaps became necrotic postoperatively. He had not received radiation therapy, and his neurosurgeon was concerned that the avascular bone flap and hardware would become exposed and infected. Although he had been referred for a free flap, it was thought that the defect would be amenable to local scalp flap closure.

Fig. 5B-11  A, The patient is seen prone with the forehead down. The T incision used for the neurosurgical procedure lends itself to the creation of three flaps. Most of the expansion through scoring and advancement will have to come from the two posterior flaps to limit forehead advancement and eyebrow elevation. B, The bone plate and hardware are seen centrally and must be covered. The posterior flaps have been scored transversely to allow advancement into the defect. The entire scalp has been undermined to allow closure. This is almost always performed, because it does not affect the blood supply in the subgaleal plane. C, Flaps advanced and closed. The wound healed without complication. (Case supplied by MRZ.)
This 78-year-old man had a squamous cell carcinoma of the scalp that required Mohs resection and had an area of exposed bone. Coverage with tissue was required to facilitate postoperative radiation therapy. Because of the patient’s age and medical comorbidity, free tissue transfer was not considered. In such a situation, the use of local scalp tissue and back-grafting with a skin graft is advisable.

**Fig. 5B-12**  
A, Preoperative oblique view of the wound with exposed bone. B, A wide-based flap of similar dimension to the wound was created, with the occipital and superficial temporal vessels in its base. The periosteum was left at the donor site to allow skin grafting. C, The flap was easily transposed and a large dog-ear was created. One should resist the temptation to fix the dog-ear, because it contains the blood supply to the flap. The donor site was skin grafted. D, Two months postoperatively, the graft and flap are well healed. Note how small the dog-ear has become without revision. E, AP view at 2 months. (Case supplied by MRZ.)
This 25-year-old woman had had a traumatic amputation of the scalp that failed attempts at replantation. Four months after skin grafting the wound, tissue expansion was scheduled. The patient had adequate hair-bearing areas for expander placement and eventual replacement of the skin graft with hair-bearing scalp.

**Fig. 5B-13**  
A, The defect after skin grafting. B, Three tissue expanders were planned to maximize scalp expansion. The proposed left lateral site is marked. C, The posterior and right lateral sites are marked.
Fig. 5B-13  D, After completion of expansion. Measurements before and after expansion were used to determine adequate expansion. One can sometimes get further expansion of the area to be resected. This relates to the proximity of expander placement and is quite common, but cannot be counted in measurements for reconstruction.  E, The priority of the reconstruction was to reestablish the anterior hairline so a large posterior flap based on the occipital artery was fashioned to accomplish this on the right, while straight advancement of the left flap formed the left hairline. The large dog-ear was left in place, and the hairline closure was delayed, because the flap turned white with full inset. Some spanning sutures are seen. This area was closed in the office 1 week postoperatively. An area of the vertex could not be closed at this procedure and was left, emphasizing the importance of waiting until the end to resect the lesion or area of alopecia to avoid the need for more skin grafting.  

F, One week after closure of the anterior hairline.  G, Four months postoperatively, the patient has a nice hairline. It is not uncommon to have some postoperative alopecia until the hair-growth cycle reestablishes itself. This patient went on to have forehead expansion to remove the forehead skin graft and further scalp expansion to remove the vertex skin graft. (Case supplied by MRZ.)
This 42-year-old man underwent resection and reconstruction with a radial forearm free flap for a squamous cell carcinoma of his upper lip. The reconstruction was functional but not aesthetic. As a secondary procedure, a mustache reconstruction was planned with a scalp flap based on the superficial temporal system.

**Fig. 5B-14**  
A, Preoperative view of the lip. Skin from sites distant from the face often provides a poor color and texture match. Mustache reconstruction is a good camouflage procedure, although not helpful in women, who often can use cover makeup.  
B, The planned flap. Allowance was made for loss of some of the arc of rotation because the rotation and placement were through a tunnel. A Doppler probe identified the vessels marked. It is critical to plan the flap with hair growth in the desired direction. The flap was first incised, partially elevated, and delayed.  
C, Two weeks after delay. The flap was passed through a subcutaneous plane. The outer skin of the lip reconstruction was resected and replaced with the scalp flap.  
D, The result is seen 1 week postoperatively and E, 4 months postoperatively. (Case supplied by MRZ.)
This child had congenital absence of heminose; the defect was treated with a Washio flap to avoid forehead scars.

Fig. 5B-15  A, Flap design based on superficial temporal vessels. B, Elevation of flap with backcut (dashed lines) to allow flap reach. C, Flap elevated in a subfascial plane. The flap is transposed easily, reaching the nose without scoring of the galea. D, Superficial temporal vessels shown. It is important to maintain these vessels as an axial supply during elevation. E, Flap inset. The scalp is temporarily grafted at 2 weeks. After division and inset, the Washio flap is returned to the scalp and the skin graft is excised. (Case courtesy Ian T. Jackson, MD.)
This patient had a low-flow vascular malformation.

**Fig. 5B-16**  
A, Malformation on the right forehead and orbit. B, Plan for surgical resection and a forehead rotation flap. C, Excision of the vascular lesion. D, The flap was elevated, with scoring of the pericranium to enlarge the flap.
Fig. 5B-16  

E, Surgical plan of closure. The flap was rotated with excess scalp medially and the excess was resected. 

F, The excision was completed and the flap rotated into the residual defect. 

G and H, The patient is seen 6 months postoperatively with no revisions. The right front orbital area has healed well, but there is some asymmetry. The eyebrow is elevated, and there is excess eyelid skin. The patient was pleased and did not want further surgery. (Case courtesy Ian T. Jackson, MD.)
This 50-year-old woman had a large basal cell carcinoma.

Fig. 5B-17  A and B, The basal cell carcinoma had eroded the frontal bone but had not invaded the dura. C and D, The resection was outlined; the planned reconstruction was with a large scalp transposition flap from the posterior area of the scalp. E, A full-thickness resection of the basal cell carcinoma was performed; this included the scalp and underlying cranium. The dura was exposed.
Fig. 5B-17  
F and G, The defect was reconstructed with bone dust harvested from the posterior skull and was covered with Surgicel. A large transposition flap based on the left temporal vessels was raised posteriorly and used to cover the defect. The defect was reconstructed with a split-thickness skin graft. 
H, Good anterior closure was achieved. The lateral dog-ear was trimmed later. The message from this case is to carefully plan the flap and its rotation using a sponge or swab. Basing the flap on a secure blood supply is essential. 
I-K, The postoperative result. Further reconstruction will be carried out by scalp expansion to reconstruct the skin grafted area. (Case courtesy Ian T. Jackson, MD.)
When large unilateral defects involving virtually the whole hemiforehead result from tumor resection, the concept advanced by Worthen may be used.

Fig. 5B-18  A and B, The technique has been applied to the right hemiforehead and upper eyelid nodular hemangioma, as illustrated in this patient. C and D, The surgical plan called for resection of the lesion and reconstruction with a forehead rotation flap. The diagram shows the proposed surgical approach and illustrates mobilization of the forehead rotation flap, as well as the planned dog-ear resection. E, The vertical height of the forehead in the midline is approximately equal to the horizontal width of the hemiforehead just above the eyebrows.
Fig. 5B-18  **F**, An incision completely within the hairline, or one initially in front of the hairline and then down to the temporal region, will allow rotation of the whole of the remaining forehead. It can be seen that to achieve good coverage of a secondary defect after excision of the lesion, scoring has begun. As can be seen in later photographs, this allows a flap that seems inadequate to easily close the defect that has been created and to achieve a nice reconstructive result. **G-J**, The vertical edge of the flap becomes the horizontal suture line. In this technique, two rotational movements are being used: the loose scalp of the temporal area is being stretched, and the lateral scalp areas on both sides are being advanced. A full-thickness scalp graft is used to provide an eyebrow. **K**, Some asymmetry of the eyebrows and the hairline may occur, but this is usually acceptable when compared with the original problem. (Case courtesy Ian T. Jackson, MD.)
Pearls and Pitfalls

- Defects of the scalp are best reconstructed with like scalp tissues.
- Tissue expansion provides the safest, most reliable technique for creating and providing like tissues for scalp reconstruction. Planning the flaps in the expanded tissue is critical for success and for best utilization of expansion.
- Most tissue expansion cases will benefit from straight advancement of flaps and excision of Burow’s triangles.
- Although the Washio flap is rarely used, the surgeon should keep it in mind when reconstructing a nose that has had multiple procedures or complications and no forehead tissues are available.
- Expanded flaps can be quite thin, and care must be taken in scoring and manipulating the flaps to avoid avulsion or ischemia.
- When there is exposed bone, a history of radiation treatment, or a wound that will not take a skin graft, one should strongly consider advancing nearby scalp into the defect and back-grafting the donor site with a skin graft. Flaps may be planned so that the back-grafting can be done in a cosmetically acceptable location or far enough away from the open wound that the skin graft should heal uneventfully. Later the skin graft can be removed by serial excision or tissue expansion at the patient’s convenience.

EXPERT COMMENTARY

Ian T. Jackson

All plastic surgeons should be capable of performing a scalp flap. This is more significant today, as we have become more and more involved in craniofacial surgery. We should also know our limitations. Coronal flaps are within the range of the plastic surgeon’s training, but intracranial procedures are in the realm of neurosurgery.

Indications

The main procedures are in the closure area to cover the dura and to protect the cranium with vascularized material, which is mainly scalp. Skin grafts will not survive on the external layer of the cranium minus pericranium because of a lack of blood supply, if such a flap is desired. This can be designed so that the pericranium will be preserved. This all requires careful planning, and it is important not to damage the lateral cranial area. This will not allow a skin graft to survive, and thus a further problem will have been created.

Recommendations

Technique

On some occasions the flap can be expanded to provide the required cover. This may be achieved by multiple incisions of the pericranium, which can provide maximal expansion. Care must be taken not to injure the deep area; necrosis may result, with exposure of the cranium. In situations in which a raw area will result, the latter will have pericranium left in place, and the area is covered with a split-thickness skin graft.
A somewhat more hazardous approach is tissue expansion. The danger lies in the potential for infection and expansion tension. The area to be expanded must be in such a position that the expander does not find its way into the defect. If this happens, the treatment should be discontinued. Sometimes there may be enough scalp tissue to use, even though the region has only been partially expanded. In other situations, removal of the expander and partial resection and reconstruction with the flap should be performed.

The expander should be positioned so that it is well away from the zone of injury. The rules of expansion are as follows: (1) an area away from the defect is chosen so the wound is not disturbed, and (2) the expansion must be very frequent, several times a day for 2 to 3 hours with small volumes (5 to 10 ml). This can prevent too much tension at each expansion. If the scalp is too tight, the volume of fluid is reduced. This can be done easily and painlessly, because the filling value is exteriorized. This situation allows expansion several times a day. Usually the patient or a relative can be trained to do this. This can also be done in children once they realize it is painless. (3) Once the expansion has been completed, the scalp flap can be designed. It is important to measure the expanded area carefully. If this is sufficient, excision and reconstruction are performed. If there is not enough skin, further expansion is performed. It is always better to have too much than too little tissue.

Complications: Avoidance and Treatment
Most complications result from a poor blood supply to the flaps, infection or exposure of the expanders, or exposed bone in the donor site that requires further surgery. Proper execution using the tips above will help to limit these problems.

EXPERT COMMENTARY
Michael R. Zenn

Advantages and Limitations
The scalp is perhaps one of the best vascularized areas of the body. This can be used to one’s advantage in reconstruction as these flaps can be quite robust. That said, long, random flaps of the scalp, especially when narrow, may necrose and foil the reconstructive effort.

Recommendations
Planning
A general rule of thumb is to design any scalp-based flaps with the aid of a Doppler device to ensure a signal in the base of any flaps designed. It is often possible to follow these vessels, mark their axial course, and create axial-based flaps that have a better blood supply than random flaps.

When defects greater than 6 cm must be reconstructed, I prefer placement of tissue expanders as the primary reconstructive technique. Two or three expanders can often be placed around the area of defect, and these should be as large as possible to fit under the existing scalp. I prefer to place these expanders through radial incisions, not longitudinally along the defect, because these incisions may dehisce during the expansion process.
Measurement of the scalp preoperatively can be helpful in determining the amount of tissue expansion required. One can compare the preoperative measurements to measurements of the postexpanded scalp to determine how much extra skin has been generated. This is then compared with the recipient site to see whether tissue expansion is complete. One should always overexpand, because once these tissue expanders are removed, the flaps will provide less than they measure because of the elastic nature of scalp flaps.

Although galeal scoring is a standard method for expanding flaps further, one must be careful when scoring expanded flaps, because they are quite thin and can be easily avulsed. Planning should rely on the expansion, and not on scoring. These expanded flaps, once advanced or rotated, are often associated with large dog-ears. These dog-ears can be excised as Burrow’s triangles; however, clinical experience shows that these dog-ears will often disappear over time as the scalp settles down to the cranium. Dog-ears can always be excised later if they do not resolve on their own after 4 to 6 months.

**Technique**

Flaps based in the temporoparietal area on the superficial temporal vessel can be quite useful for eyebrow and mustache reconstruction. These flaps are centered over these vessels but can often be congested on initial elevation. If the flaps are to be passed in a subcutaneous plane to the eyebrow or mustache,

**Take-Away Messages**

I strongly recommend a delay procedure with these flaps to avoid postoperative congestion or ischemia from compression of the pedicle. These delays are usually accepted by the patient, since they are correcting secondary deformities and there is the luxury of time.

**Bibliography With Key Annotations**


Anophthalmic socket reconstruction is a challenging problem in plastic surgery. The authors had described a prefabricated superficial temporal fascia island flap and used this technique in more than 50 enucleation patients with severe socket contraction, ending in excellent or good results for 28 years (Altindas-1 procedure). However, the flap was not suitable for exenteration patients with complete eyelid loss. The technique was modified and used in exenteration patients (Altindas-2 procedure). In this two-stage procedure, the temporoparietal fascia is prefabricated with a full-thickness skin graft from the retroauricular area, and a strip of scalp is preserved at the middle of the flap. The flap is transferred to the orbit through a subcutaneous tunnel at the second stage. The prefabricated flap is used for the reconstruction of eyelids and periorbital skin; a scalp island is used for the reconstruction of lid margins and eyelashes; and the neighboring bare temporoparietal fascia is used for the augmentation of the periorbital soft tissues. The orbital lining is elevated as a centrally based skin flap and used for the reconstruction of the eye socket, fornices, and posterior lining of the eyelids. The technique was used successfully in five total exenteration patients with complete eyelid loss. In one patient the ipsilateral temporal island flap was used previously, so the flap was prepared from the contralateral site and transferred to the anophthalmic orbit as a free flap 5 weeks later. By means of this procedure, it is possible to reconstruct a stable eye socket that is suitable for ocular prostheses, upper and lower fornices, periorbital skin with good color matching, naturally looking eyelids with eyelashes and lid margins,
and medial and lateral canthal areas. It is also possible to improve periorbital soft tissue atrophy, which is a significant problem in patients who had radiotherapy previously. Free transfer of the flap provides a new solution for reconstruction in patients who had prior surgery.


Forehead and scalp reconstruction comprises a diverse and complex set of defects. Repair must be performed with minimal disturbance to surrounding structures such as the eyelid, eyebrow, and hairline. Care must be taken to maintain symmetry between sides. The authors addressed the options for the management of forehead and scalp defects, including healing by secondary intention, skin grafts, local flaps, free flaps, tissue expansion, and negative pressure treatment. They also discussed the advantages and disadvantages of each repair option while providing a framework from which to plan scalp and forehead reconstruction.


This article reviewed common methods of reconstructive surgery in patients with wounds that involve the scalp, including primary wound repair, healing by secondary intention, and the use of skin grafts, local tissue flaps, regional myocutaneous flaps, and microvascular free flaps. The authors discussed aspects of the reconstruction that affect the aesthetic outcome, including preservation of the hairline and hair follicle orientation, scar camouflage, avoidance of alopecia, and secondary restoration of alopecia.


Temporoparietoccipital flaps (Juri flap) and temporoparietal flaps (Elliott) were commonly performed in previous decades but have largely fallen out of favor with the development of follicular unit hair transplantation. Besides high complication rates, these procedures created straight, abrupt hairlines, posterior hair direction, hair density that was disproportionately thick, and blunt temporofrontal angles. Because many patients live with cosmetic deformities created by previous flap procedures, the author presented a series of techniques to restore these patients to normal cosmesis: (1) undulating follicular unit grafting anterior to the hairline, (2) removal of 2 to 3 mm cylinders of hair-bearing scalp at the anterior hairline, (3) removal of 2 to 3 mm cylinders of hair-bearing scalp from within the flap itself, and (4) appropriate fusiform excision techniques to create a normal temporofrontal angle. The combination of these techniques has restored a very natural cosmesis in patients who have poor aesthetics after flap surgery.


The temporoparietal galeal flap has been rediscovered as a useful tissue transfer technique. It is the only single-layered fascial flap that can be transposed into the craniofacial and head and neck region on its vascular pedicle. In the 1990s, it was used extensively in the surgical reconstruction of a wide variety of defects in the craniofacial area, ranging from scalp and auricle defects to nasal and maxillo-orbital repair to all types of intraoral and even mandibular and pharyngeal reconstructions.


Limited skin paddle size, peripheral thinning, or lack of cerebral expansion after radiotherapy may necessitate secondary sculpting after latissimus free flap reconstruction of large scalp defects. This series presented a novel modification of the myocutaneous latissimus dorsi free flap for use in large scalp defects. After superficial artery isolation, titanium mesh is placed into the calvarial defect to recapitulate the inner table. The myocutaneous latissimus flap is harvested in standard fashion, deepithelialized, and inverted. The skin paddle is placed over titanium mesh to fill the calvarial defect, then sewn over a drain. The inverted latissimus muscle is shaped over the defect and extended peripherally beneath the pericranium. The flap is sewn to the scalp internally using a vest-over-pants suture pattern, and
the thoracodorsal and superficial temporal vessels are anastomosed and left facing outward. Unmeshed skin graft is draped over the muscle, and vessels are then sutured loosely. Patients with complex scalp defects whose soft tissue defect exceeded the size of latissimus skin paddle available with primary closure were considered eligible for inverted latissimus free flap reconstruction. Follow-up ranged from 6 to 12 months. Over a 2-year period, five patients underwent inverted latissimus free flap reconstruction. Scalp defects ranged in size from 10 by 8 cm to 17 by 11 cm. The calvarial defect was smaller than the soft tissue defect in all cases. All flap donor sites were closed primarily. All five flaps took, and donor site outcomes were acceptable. Aesthetic outcomes were satisfactory with well-contoured, calvarial-shaped results. Cosmesis was most notably limited by skin graft joint lines. No patients underwent secondary surgical revision. The inverted myocutaneous latissimus free flap is a safe and effective method for reconstructing large or irradiated scalp defects.


The scalp provides a relatively limited amount of excess tissue that can be used in reconstructing significant scalp defects that arise most often from oncologic resection or traumatic loss. Scalp reconstruction encompasses a broad spectrum of flaps, grafts, and techniques that should be readily available to the facial plastic surgeon treating this patient population. Meticulous attention to detail, particularly in the planning and early postoperative periods, is associated with gratifying results in most patients. This article presented defect analysis and discussion of reconstruction options, as well as discussion of successful reconstructive surgeries.


Parry-Romberg syndrome is characterized by progressive hemifacial atrophy that is the lack of tissue (generally, soft tissue and, rarely, bone and muscle) in the atrophic area of the face. The cause and incidence of this pathologic process are uncertain, but it is relatively rare and self-limited. The authors presented a 21-year-old female patient with progressive hemifacial atrophy who underwent reconstruction with a composite galeal frontalis flap. Although many reconstructive methods have been described, reconstruction of both eyebrow deficiency and forehead atrophy with composite galeal frontalis flap had not been described previously.


For a large lesion of the scalp (up to 50% scalp loss), restoration of the scalp with a hair-bearing scalp flap to achieve a pleasing aesthetic outcome and hair growth matched to the direction of the lesion—especially for a hemiscalp defect in children—often becomes very challenging for plastic surgeons. Treatment was performed in 18 children with severe hemiscalp losses after burns. The technique was carried out by initially positioning a tissue expander in the subgaleal pocket of the scalp and serially inflating it with normal saline solution at 5- to 7-day intervals for about 3 months. Therafter a “flying-wings” expanded scalp flap was designed by combining the principles of advancement and rotation flap transplantation. This design was based on at least one nominated vascular system of the scalp used as the pedicle, with the wings often working to correct the distant part of the lesion in which the hair direction is greatly changed. After the lesion was excised, the expanded hair-bearing flap was advanced and rotated to the recipient site when the expander was removed. The flap used for hemiscalp reconstruction could be transferred to repair the hemiscalp loss totally (17 patients) or mostly (1 patient) in a single—tissue expansion process without flap necrosis. The patient with a remaining lesion was treated completely with a secondary tissue expansion in the postauricular area. All patients showed good aesthetic results, with the direction of hair growth well matched at the recipient site.


A small group of patients with complex head and neck cancer present with problems of wound healing following radiotherapy and reconstructive surgery. Providing skin coverage to the neck in these cases is often required and presents a challenge to the reconstructive surgeon. The authors presented the use of
a pedicled scalp flap based on the occipital artery for such defects. This flap is an axial patterned scalp flap that incorporates hair-bearing skin. It may be up to 15 cm wide and can reach beyond the midline of the chin. The anatomy of the flap was described and its use illustrated in three cases. This flap is a useful addition to the options for reconstruction of neck defects in patients with head and neck cancer.


To demonstrate the use of multiple large local flaps in the reconstruction of large scalp defects, the authors presented a retrospective review of four cases in which the “banana peel” method of scalp reconstruction, originally described by Orticochea, was used as a method for closure of moderately large to extensive scalp defects. In all four cases, closure of the scalp defects was accomplished. Major morbidity included hair-bearing skin in the forehead in one patient, an inconsequential small flap dehiscence requiring closure in the same patient, and a partial loss of a small skin graft resulting from a donor site defect in one patient. Although other techniques may be optimal for the management of most scalp defects, such as one- or two-flap rotation-advancement flaps in small to moderate-sized defects and microvascular free tissue transfer and secondary tissue expansion for larger defects, the authors concluded that the multiple-flap reconstruction method as described by Orticochea may be useful in a small subset of patients, including older, severely debilitated patients who would be optimally treated with microvascular tissue transfer but cannot tolerate lengthy general anesthesia, and young patients who will not accept a significant area of alopecia that might exist with other techniques, such as healing by secondary intention, skin grafts, or free flaps.


Chiari III malformation (CM3) is rare among Chiari malformations (I-IV). Its definition has been expanded to include caudal medullary displacement and hindbrain herniation into encephaloceles in lower occipital and high cervical regions. Prognosis is recorded as dismal, with respect to survival and functional outcome. The authors described the presentation, radiologic evaluation, and repair of this malformation by means of methylmethacrylate cranioplasty and an occipital scalp rotation flap for closure. Outcome after surgery is also addressed. Adequate closure of the defect and protection of underlying structures was achieved without undue stress at the incision site. This method of closure can be considered in cases of large occipital and cervical encephaloceles with poor skin coverage and added osseous anomalies around the foramen magnum.


In male burn victims, scarring may cause grotesque disfigurement of the upper lip and lower face. There are many ways to address the problem, ranging from simple skin grafting to complex flaps. Bipedicile scalp flaps are used sporadically for reconstruction of the upper lip. The authors described the use of bitemporal artery hair-bearing flaps for reconstruction of the mustache and beard area in nine cases as a substitute for deformed facial skin. The results indicated that the scalp flap is one of the best-matched flaps for reconstruction of the middle and lower parts of the male face. By choosing a proper-sized flap, use of a tissue expander can be omitted, the donor site may be closed primarily, and early return of the patient to normal life is assured. Although the width of the flap is not sufficient to cover the entire lower face and cheeks, it is adequate to imitate a normal face and provide a pleasant appearance.


The superficial temporal artery and vein are often considered suboptimal recipient vessels because of anecdotal reports that they are unreliable and prone to spasm. This is unfortunate, because their position greatly facilitates reconstruction of the scalp and orbit. The authors presented their experience...
in 28 patients who underwent microvascular craniofacial reconstruction of oncologic defects using the superficial temporal artery and vein as recipients over a 4-year period at a single institution. Rates of vessel thrombosis, total flap loss, and partial flap loss were not significantly different from 282 flaps anastomosed to neck vessels. With knowledge of the anatomy and proper technique, the superficial temporal artery and vein are reliable and available in most patients and can facilitate microvascular orbit and scalp reconstruction. The proximity they offer allows more flexibility in flap pedicle length requirement and avoids the use of vein grafts. Caution should be exercised in patients with a history of radiation therapy.


Defects of the scalp often pose a reconstructive challenge in dermatologic surgery. The authors reported their experience with the H-plasty type of bilateral advancement flap for the closure of small to medium-sized scalp defects that cannot be closed primarily. Sixty-nine 1.5 to 3.0 cm diameter scalp defects resulting from Mohs micrographic surgery that could not be closed primarily were identified over the 2-year study period. All 69 defects were closed entirely with the bilateral advancement flap, and there were no significant complications. The H-plasty type of bilateral advancement flap allows appropriately selected scalp defects that might not be readily closed primarily to be easily repaired with the use of local skin, providing an attractive alternative to other flap techniques, skin grafting, and healing via secondary intention. The limitations of this study were that the results were based on a retrospective single-surgeon experience and there was no long-term follow-up scheduled to evaluate the final cosmetic outcome of the repair.


The purpose of this study was to assess the appropriateness of the clinical indications for the various reconstructive methods for burn alopecia and to suggest an algorithm for individualized reconstruction. A review of 83 patients who underwent reconstruction for burn alopecia between 1995 and 2007 was conducted. Demographics, associated injuries, preoperative findings, surgical techniques, and postoperative complications were collected. From these data, the authors classified reconstructive methods based on the area, the scar quality, and the location of the burn alopecia and investigated the clinical outcomes. Reconstructive methods included hair grafting (13), scalp reduction (21), scalp extension (14), and scalp expansion (37). Twenty-eight patients had surgical complications, most related to alloplastic implants used in scalp extension and expansion. The reconstructive method should be tailored to the conditions of the burn alopecia. Because scalp extension and expansion are associated with a high rate of complications, the authors recommended the use of these methods for large, poor-quality burn alopecia. On the other hand, hair grafting and scalp reduction are more appropriate treatment options for relatively small, good-quality burn alopecia.


The authors described options and indications for different surgical reconstruction techniques after resection of large skin tumors on the scalp, taking into account an interdisciplinary approach for craniofacial surgeons, dermatologists, and neurosurgeons, and to evaluate complications and postoperative outcomes. Forty-two surgical reconstructions were performed in 39 patients with large skin tumor resections on the scalp and/or the forehead who were treated between 1995 and 2005. The medical histories, surgical treatment, postoperative complications, follow-up, and outcome were evaluated. The excision defects measured an average of 146 cm (range 80.6 to 546 cm). The most common methods for defect closure were multiple rotation-advancement flaps. Six patients were treated with split-thickness skin grafts after bone drilling for inducing granulation tissue to grow. Free latissimus dorsi muscle flaps were used in eight patients and radial forearm flaps in four. Postoperative complications were rare. An algorithm for the surgical approach to large scalp defects was presented.

Scalp necrosis is an infrequent complication of surgery for Moyamoya disease, which is more prevalent in the parietotemporal area. Because scalp vascularity is severely compromised after Moyamoya disease surgery, reconstruction of defects with local scalp tissue is challenging. To cover defects, a flap is needed that is highly vascularized and has great mobility and territory to avoid existing scars. After tracing ipsilateral occipital artery, an advancement flap that was based on occipital artery and vein was designed to fit the defect. The flap was elevated in the subperiosteal layer and advanced without tension to cover the defect. Occipital pedicle V-Y advancement flaps were used in seven patients who had scalp necrosis of the parietotemporal area and a mean defect size of 8.7 cm. There were no complications such as flap necrosis, infection, or recurrence of the defect in any of the patients during 9-month follow-up. Occipital pedicle V-Y advancement flap is a useful alternative flap for scalp defects after surgical treatments that compromise scalp vascularity, such as Moyamoya disease surgery.


The authors summarized traditional and advanced techniques used to reconstruct defects of the scalp, from small defects that can be closed primarily to significant defects that require free tissue transfer. Increased use of tissue expanders, advancement rotational flaps, and hair transplantation has resulted in improved cosmetic outcomes for larger defects of the scalp. Free tissue transfer has provided a revolutionary method of reconstructing subtotal and total defects of the scalp, in particular those associated with neoplasms. Advances in techniques of scalp reconstruction have provided improved cosmetic appearance and decreased morbidity for scalp reconstruction.


A complete loss of palpebral tissue can occur from a congenital malformation or after tumor resection or traumatic injury. The authors presented their clinical experience with upper eyelid reconstruction in children using the Guyuron retroauricular island flap. Five cases of severe eyelid defects in children ages 5 days to 10 years (3 patients after enucleation and 2 with upper eyelid coloboma of approximately two thirds of the upper eyelid surface) were treated with this technique. In all cases, optimal closure of the eyelid fissure was achieved and corneal exposure clinically improved. On average, 15% of the initial flap surface was lost. Only one major complication (40% flap necrosis) was reported in the postoperative period. This reconstructive technique can provide complete eyelid reconstruction, leaving an inconspicuous scar and causing limited morbidity at the donor zone.


The repair and/or removal of an existing defect is often difficult; however, the appearance of the repair is often the most difficult challenge. Thus an understanding of normal hair morphology, anatomy, and physiology is important to achieve long-lasting, satisfying results. We must anticipate future hair loss, communicate that to the patient, and consider it in surgical planning. In addition, residual effects such as radiation therapy after cancer resection may pose additional challenges. Today many extraordinary techniques are available that allow creation of natural and almost undetectable hairlines, but these techniques are often unsuitable for repairing large scarred areas of hair loss. By using more traditional techniques of scalp reduction and tissue expansion, however, excision of many large, scarring defects can be accomplished. Combining older methods with modern hair restoration surgery permits the satisfactory treatment of many previously untreatable conditions.


Scalp reconstruction after oncologic resection can be challenging. Wide surgical resections, in combination with conorbid conditions such as infected alloplastic material, cerebrospinal fluid leak, or devascularized bone after craniotomy necessitate healthy, vascularized tissues for reconstruction. Although primary closure is feasible in some cases, the mainstay of treatment involves local tissue rearrangement with or without split-thickness skin grafting. In addition, free tissue transfer is an important adjunct to therapy.
in patients with poor local tissues. Careful analysis of the defect and local tissues can help tailor the method of reconstruction and result in satisfactory closure in a majority of patients.


Rotation flaps constitute a time-honored method for repair of small to moderate scalp defects, even in the era of microsurgical reconstruction. A case of cicatricial pressure alopecia that was successfully repaired using the Bardach modification of the curved tripod flap confirms the value of this flap in scalp reconstruction. The main advantages of this method are the natural appearance of the final result because hair orientation is preserved, and wound-closure tension is distributed uniformly over a wide peripheral area of the scalp, although extensive undermining is generally required.


Finding a useful reconstructive algorithm lacking for scalp reconstruction after ablative surgery, the authors evaluated their experience—73 procedures performed in 64 patients over 15 years—and identified an appropriate reconstructive strategy. Reconstructive methods, independent factors, and outcomes were analyzed. Techniques for reconstruction included primary closure, grafts, and local and distal flaps. A correlation between reconstructive technique and complications could not be demonstrated. However, an increased incidence of complications was correlated with a history of radiation, chemotherapy, cerebrospinal fluid leaks, and an anterior location of the ablative defect. Important tenets for successful management of scalp defects are durable coverage, adequate debridement, preservation of blood supply, and proper wound drainage. Local scalp flaps with skin grafts and free tissue transfer remain the mainstay of reconstruction in most instances.


Noma, aptly named the “face of poverty,” is a scourge with a mortality rate of up to 90% that affects some 140,000 people each year, predominantly children in the sub-Saharan “noma belt.” Survivors of the acute polymicrobial attack suffer severe gangrenous facial disfigurement from loss of facial tissue and scarring. Surgical reconstruction of noma defects is a major challenge, especially in Africa, where most cases occur. The authors reported the case of a 40-year-old Somali man who presented with severe facial disfigurement, including total absence of both upper and lower lips and inability to open his mouth. After a failed initial reconstruction, a combination of platysma flaps and a left deltopectoral flap provided mucosal lining, while a scalp visor flap served to recreate upper and lower lips, the beard, and the mustache. The scalp visor flap offers a simple but extremely versatile tool for use in midfacial reconstruction, especially in men, providing neolip tissue, a mustache, and a beard. This is the first report of a simultaneous total upper and lower lip reconstruction using a scalp visor flap in the English literature. The authors also emphasized a process of transfer of skills to enable local surgeons to effectively manage the challenge that noma presents.


The authors carried out a clinical study of all their patients who underwent reconstructions with occipitocervicodorsal flaps between 1994 and 2003 and analyzed the outcomes of the surgery. The reconstructed areas ranged from the cheek to the anterior chest. Twenty-eight patients underwent reconstruction with microvascular augmented occipitocervicodorsal flaps, and four were reconstructed with single pedicle occipitocervicodorsal flaps. In five cases, distal partial necrosis was observed. The largest flap was 43 by 23 cm (with a 5 by 5 cm pedicle). In the microvascular augmented occipitocervicodorsal flaps, the circumflex scapular artery and veins were used in 28 cases, and dorsal intercostal perforators were used together with circumflex scapular artery and veins in five cases. Follow-up was
1 to 8 years. Neck scar contractures were released in all cases, and good results were obtained not only functionally but also aesthetically. In an anatomic study, the authors used 20 preserved cadavers and obtained angiograms of the dorsal region. Five cadavers were used to confirm the territory of each of the vessels that are closely related to the occipitocervicodorsal flap (occipital artery, transverse cervical artery, circumflex scapular artery, and dorsal intercostal perforator artery). Each anatomic territory was clearly seen and its area identified.


The advent of tissue expansion began an era of aesthetically reconstructed scalp alopecia by providing a large hair-bearing scalp area with acceptable hair density. However, residual scalp alopecia and wide visible scars still raised aesthetic problems. The hair follicle transplantation carries the possibility of producing a more natural scalp, because both the desired hair density and the natural direction of the hair can be reproduced using this procedure. Our study group consisted of 62 patients (41 men and 21 women) with a mean age of 26.3 years. The median age of suffering a burn to the scalp was 3 years. The first reconstruction for all patients was the expanded flap coverage; in three patients, two-stage expanded flaps were used. Five patients underwent hair follicle transplantation after they had undergone expanded flap coverage. Expanders (n = 86) were placed in 62 patients, with a total of 9 major and 3 minor complications. The overall results after expanded flap reconstruction and hair follicle transplantation were excellent (43 patients), good (18 patients), and poor (1 patient). The visible remaining alopecia and marginal scar after the procedure, especially on the anterior hairline of the forehead and the sideburns, can be refined by hair follicle transplantation. This report also suggests the possibility that cicatricial scalp alopecia with intact deep tissue can be restored by hair follicle transplantations using a hair transplanter.


Calvarial burns are extremely rare and pose a difficult challenge for both burn and reconstructive surgeons. Reconstruction of these injuries depends on the depth of invasion and the amount of tissue loss. Fourth-degree burns include damage to the calvarium and the underlying dura and/or cerebrum. Historically, these wounds have been treated conservatively. The authors detailed two cases of electrical fourth-degree calvarial burns with large soft tissue defects as well as loss of calvarium and dura with cerebral herniation. Each patient presented to Shriners Burn Hospital in a delayed fashion with infected wounds necessitating immediate intervention. In both patients, the wounds were debrided and covered with a bipedicled superficial temporal artery scalp flap. The donor sites of each flap, as well as the remaining areas, were skin grafted. This flap provides immediate vascularized coverage in wounds that could not be treated conservatively. In the presence of sepsis and other severe injuries, where more complicated flaps are risky, this flap provides a reasonable and reliable method of calvarial coverage.


Aplasia cutis congenita (ACC) is a rare congenital defect of skin and subcutaneous tissue, more rarely of periosteum, skull, and dura. The lesions can involve any location, but most common are scalp defects. The authors reported on the successful treatment of three large defects of the scalp with skull involvement in a newborn girl by early debridement and defect closure with two opposed scalp rotation flaps and an occipital split-thickness skin graft.


The authors presented a case with a 5 by 8 cm full-thickness defect in the temporo-parietal region that was managed with an extended posterior auricular artery–based flap in one stage. The flap was shaped like a “gandasa” (an axelike agricultural implement used in Punjab, India). This allowed ample movement of the flap and permitted a V-Y closure of the donor site. The flap also received additional blood supply from the ipsilateral superior auricular artery.

The management of posterior scalp defects with “similar” tissue can be challenging. The currently available techniques of transposition-rotation result in the creation of unwanted dog-ears, changes in the direction of hair growth, and patches of skin-grafted areas with alopecia. The authors described a new method of reconstruction of full-thickness scalp defects in the occipital region by moving the locally available scalp tissue as for a V-Y advancement flap. The island flap is based on the ipsilateral occipital artery in the substance of occipitalis muscle. The donor sites can be closed primarily and the operation performed in a single stage. A total of seven patients underwent reconstruction over a 2-year period with this technique. The defects in the posterior scalp region resulted from electrical burns (2 patients), tumor excision (2 patients), encephalocele excision (1 patient), or posttraumatic loss of the scalp (2 patients). In all the patients, the underlying bone was exposed. The remaining scalp tissue in the vicinity of the defect was moved as a V-Y advancement flap either unilaterally or bilaterally, depending on the size of the defect. The pedicle of the flaps contained ipsilateral occipital vessels at the base. The flaps were raised in the subgaleal plane and the pedicle included ipsilateral occipital artery in the substance of the occipitalis muscle. The donor area was closed primarily in all cases. All of the flaps survived completely; one patient had postoperative superficial loss that eventually healed with dressings. All wounds healed with luxuriant hair growth, except in one patient who had partial alopecia in the transferred flap, although the flap survived completely.


The authors presented three cases in which reconstruction of the temporal, frontoparietal, and midline regions was performed with the use of island hair-bearing scalp flaps. In addition, they described a new vascularized island scalp flap design that can potentially repair large scalp defects.


This article reviewed the surgical anatomy of the scalp and forehead and presented an algorithm for decision-making in reconstructive surgery of the region. Nonmicrosurgical techniques were briefly reviewed. The microsurgical reconstruction of scalp and forehead defects differs from the more common oropharyngeal reconstructions in several ways, including flap choices, choices for recipient vessels, and the opportunity to use conventional and microsurgical techniques simultaneously to improve outcomes. Each of these considerations was reviewed and the authors’ preferred techniques presented.


Although the vascular supply of the occipital region of the scalp is usually considered to depend on the occipital arteries, the authors stated that in their clinical experience the importance of the posterior auricular arteries seems to have been underestimated. They considered the occipital artery to be the main artery to the vascular supply of this region. The role of the posterior auricular artery has not been clearly investigated. To describe the cutaneous territories of these two arteries, 20 cadaver occipital areas were dissected after bilateral injection of colored latex (40 occipital and 40 posterior auricular arteries studied), and four occipital areas were dissected after selective injection of china ink in the occipital and posterior auricular arteries (4 occipital and 4 posterior auricular arteries injected). The occipital artery was deep from its origin to the arch constituted by the insertions of the trapezius and sternocleidomastoid muscles. Then the occipital artery was becoming superficial while ascending to the vertex. The cutaneous territory of the occipital arteries was paramedian and median (38% of the occipital area). The posterior auricular artery was superficial in the auriculomastoid sulcus and divided into three branches: auricular and mastoid as usually described, and a third terminal branch that they called the “transverse nuchal artery.” The posterior auricular arteries supplied the major part of the occipital area of the scalp (62%).

Large temple and suprabrow lesions can pose a reconstructive challenge. When the lesion extends anterior to the hairline, aesthetically acceptable local flaps may be difficult to design. The authors described a modified scalp flap (part Converse scalping flap and part scalp rotation flap) that can be tailored to reconstruct a variety of difficult temple and suprabrow lesions while maintaining eyebrow position. The modified scalp flap is raised in a subgaleal plane until approximately 2.5 cm above the brow. At this level, dissection proceeds in the subcutaneous plane to protect the frontal branch of the facial nerve and to keep the flap thin. (The key to the modified scalp flap is the dissection plane change that protects the frontal branch of the facial nerve.) The extent of posterior subgaleal dissection is dictated by the amount of anterior rotation necessary. A temporal dog-ear is removed subfollicularly to permit modified flap rotation and preserve the superficial temporal artery. The modified scalp flap was used to reconstruct temple and suprabrow lesions in 10 patients ranging in age from 4 months to 22 years. There were no complications. Four typical cases were presented. Temple and suprabrow lesions can be excised and successfully reconstructed in one stage using a modified scalp flap that is extended from the hair-bearing scalp onto the glabrous skin of the forehead. This novel modified scalp flap prevents eyebrow/hairline distortion and avoids facial nerve injury.


ANATOMIC LANDMARKS

Landmarks  The flap occupies the area lateral to the nasolabial fold and extends from midcheek down to the mandibular line.
Size  $2 \times 5$ cm.
Composition  Cutaneous.
Dominant Pedicle  Angular artery.
Minor Pedicle  Alar branches of the superior labial artery.
Nerve Supply  Infraorbital nerve.
Section 5C

HEAD AND NECK

Nasolabial Flap

CLINICAL APPLICATIONS

Regional Use
- Nose
- Upper lip
- Lower lip
- Cheek
- Intraoral

Specialized Use
- Nose
- Lip
ANATOMY OF THE NASOLABIAL FLAP

Fig. 5C-1

Dominant pedicle: Angular artery perforator
ANATOMY

Landmarks
The tissues that compose the nasolabial flap lie directly over the angular artery, which is the end vessel of the facial artery. These tissues lie lateral to the nasolabial fold and extend from the midcheek above the ala down to the mandibular line.

Composition
Cutaneous.

Size
2 × 5 cm.

Arterial Anatomy

Dominant Pedicle  
**Angular artery**

**Regional Source**  
Facial artery.

**Length**  
1 cm.

**Diameter**  
0.5 mm.

**Location**  
The facial artery can be palpated along the mandibular border within 3 cm of the mandibular angle. A line can be drawn from this point to the ala. The vessel runs below the facial musculature in this area and sends branches to the flap throughout its length.

Minor Pedicle  
**Alar branches of the superior and inferior labial artery**

**Regional Source**  
Facial artery.

**Length**  
1 to 3 mm.

**Diameter**  
0.3 mm.

**Location**  
These small vessels enter this area of the flap at the level of the ala.

Venous Anatomy
Paired venae comitantes accompany the major and minor pedicles.

Nerve Supply
This area is innervated by the infraorbital nerve. This is not a sensate flap.
VASCULAR ANATOMY OF THE NASOLABIAL FLAP

Superiorly based flap

Radiographic view

Inferiorly based flap

Radiographic view

Fig. 5C-2

Dominant pedicle: Angular artery (D)

Minor pedicle: Alar branches of superior labial artery (m)
**FLAP HARVEST**

**Design and Markings**

*Superiorly Based Nasolabial Flap*

The flap is designed in an elliptical pattern that abuts the nasolabial fold and encompasses the cheek tissue overlying the angular artery. Depending on the defect to be reconstructed, a template may be placed on the cheek to guide accurate flap design. The width of the flap is limited by the ability to mobilize the cheek tissues and close the flap donor site primarily. When the nasolabial flap is used as a two-stage flap, one must take into account the bulk of the pedicle and the extra tissue needed to rotate the tissue to reach the reconstructive site.

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**Fig. 5C-3**

Skin island design based on superior subcutaneous pedicle
Inferiorly Based Nasolabial Flap

The skin design for the inferiorly based flap is similar to that for the superiorly based flap but extends more superiorly. Again, a template for the site to be reconstructed can be transposed to the cheek so that the flap dimensions are correct. Unlike the superiorly based flap, rotation and placement of the inferior flap are made easier because of the mobility of the cheek tissues.

Patient Positioning

For both inferiorly and superiorly based nasolabial flaps, a supine position provides optimal exposure.
GUIDE TO FLAP DISSECTION

Superiorly Based Nasolabial Flap

Once the flap has been designed, a base of tissue at the superiormost aspect of the flap that is near the alar base should be marked for preservation. This is a 1.5 by 1.5 cm area of tissue where all subcutaneous attachments will be left intact. The vessels in this region are underneath the facial musculature but perforate in this area. The flap may be quickly elevated from caudal to cephalad, leaving facial musculature at the base and elevating skin and fatty tissue. Once the flap has been elevated to the area marked as the base of the flap, no further dissection is performed, and the flap is rotated. In some cases, flap rotation will require incising the flap in its entirety along its design. This may aid in rotation. The flap must not be overrotated, which would occlude the blood supply at the base.

Fig. 5C-5  A, The flap is based high on the side of the nose and consequently has a smaller transposition. B and C, The high-based flap avoids the nose-cheek concavity but creates another problem. D, This flap almost always pincushions and may take time to resolve.
Fig. 5C-5  E-G, The nasolabial transposition flap is useful for closure of defects of the upper cheek. The donor site of the nasolabial fold is plentiful, and this tissue excess increases with age. The flap is based superiorly and is transposed at 90 degrees to close the defect. The donor site is close directly.
Inferiorly Based Nasolabial Flap

After the design has been marked, the base of the pedicle is marked with a 1.5 by 1.5 cm area. A Doppler probe can be used to confirm the path of the angular vessel of the facial artery to ensure it is within the base. The flap is quickly incised and elevated, maintaining all subcutaneous fat with the flap and leaving all facial musculature intact. Once the flap is elevated to the rotation point, the flap is rotated into position. Sometimes full incision of the skin paddle is required to allow rotation. Rotation of the flap must not in any way occlude the vascular pedicle.

**Fig. 5C-6**  
A, A basal cell carcinoma is excised and reconstruction is planned with an inferiorly based nasolabial flap.  
B-D, The flap is elevated above the facial muscles, taking care not to damage the underlying facial nerve branches. It is transposed to the lower lip and sutured into position. The donor defect is closed directly.
FLAP VARIANTS

- V-Y advancement flap
- One-stage flap
- Two-stage flap

V-Y Advancement Flap

This flap lends itself to advancements to the upper lip and nose as a V-Y advancement flap because of the mobility of the cheek tissues and the fact that the flap is supplied by perforating vessels from below the muscle that come up through the subcutaneous fat and remain intact with advancement. This flap offers excellent color match for the facial reconstructive site, and the donor site scars can be placed in areas that are aesthetically acceptable. The flap design neighbors the defect and is designed in the same area as the standard nasolabial flap. The flap is incised on all sides, and minimal spreading and dissection are performed around the periphery of the flap. Simple release of the surrounding skin will allow advancement and further spreading, and deeper dissection can allow even more advancement. Undermining of the triangle of the skin of the flap should be limited to a few millimeters.

One-Stage Flap

When the nasolabial tissues border the defect area, the superiorly or inferiorly based nasolabial flap can be directly transposed into the defect and the donor site closed primarily. No attempt is made to revise dog-ears at this stage, because this area contributes blood supply to the flap. This excess can settle over time or be revised 4 to 6 months later (see the Flap Harvest section).
Two-Stage Flap

Often the delicate anatomic details of the commissure or alar crease have not been violated during the trauma or cancer resection, and it is advisable to maintain these areas. The nasolabial tissues can be used as a staged reconstruction in which the flap is transposed over normal tissues and secured to the recipient site. This leaves the underside of the pedicle temporarily exposed, but this can be dressed and the donor site temporarily closed. After allowing 10 to 14 days for vascularization from the recipient site, the flap base is divided and the flap is inset.

Fig. 5C-8
ARC OF ROTATION
Reconstructions of the upper lip, nose, and upper cheek, as well as lining flaps for the nose, are based superiorly for the easiest arc of rotation. An entire upper lip and a midline nasal defect can all be reached with a nasolabial flap.

Inferiorly based flaps are used for reconstruction of the lower lip, intraoral region, and nearby cheek. Depending on the flap design, the flap easily reaches to the midline centrally and to the preauricular area laterally.

Arc to nose

Arc to lower nose, upper lip, and oral cavity

Fig. 5C-9
FLAP TRANSFER
Flaps are transferred as a direct transposition, a V-Y advancement, or a two-stage inset with secondary division. Which application to use for a given reconstruction is at the surgeon’s discretion and is often based on the defect, the desired donor scar, the arc of rotation, and the pedicle reach.

FLAP INSET
All flap variants follow the principles of layered closure and minimizing tension on flaps. For two-stage flaps, a dressing is required for the underside of the pedicle until division and inset of the flap. Tubing of these small flaps is not recommended.

DONOR SITE CLOSURE
With all variants there is excess tissue in the cheek that allows subcutaneous cheek advancement medially, and closure. If the flap design abuts the nasolabial fold, the advanced cheek will leave a scar in the area of the nasolabial fold, which leaves the most aesthetic donor scar. In a two-stage approach, the donor site is temporarily closed. On division and inset of the flap, a portion of the flap could be returned to the cheek area. Again, the goal is to leave a single scar within the nasolabial fold to give the best possible aesthetic to the donor site.
CLINICAL APPLICATIONS
This 67-year-old woman had a basal cell carcinoma of the alar crease of the nose and underwent a Mohs resection.

Fig. 5C-10  A, In a Mohs resection, a full-thickness resection of the entire ala and alar base with some cheek loss is not uncommon for a basal cell carcinoma in this area of the face. The amount of tissue loss should not be underestimated, but a forehead flap is not necessary and can be saved for future cancers. The nasolabial flap is an excellent choice for isolated alar reconstruction or in combination with other local flaps for complex defects.  B, Internal nasal flaps provide lining, and conchal cartilage provides structure to the reconstruction. A template of the defect is transposed to the cheek for transfer as a superiorly based nasolabial flap. The arrows denote the nasolabial fold and her marionette line so the flap can be designed to abut the line and leave the donor scar in these lines.  C, Basal view shows the amount of tissue needed to re-create the ala.
Fig. 5C-10  D, Stage one inset of the flap with cheek undermining to close the donor site (lateral view). E, Basal view following closure. F, One month later, the patient underwent division and inset of the flap, with some thinning. She is seen here 7 months after the division and inset (oblique view). G, Basal view. (Case supplied by MRZ.)
This 67-year-old man had a squamous cell carcinoma of the upper lip. A Mohs resection was performed, and he required upper lip reconstruction.

Fig. 5C-11  A, It can be seen that the alar base was removed, with a significant portion of the hair-bearing upper lip. The vermillion was preserved. B, First, a wedge excision of 20% of the upper lip was performed. This lessens the reconstructive burden so there is a smaller wound, allowing a V-Y nasolabial advancement. The flap design abuts the nasolabial fold for the best donor scar. C, After flap advancement and inset. The cheek was undermined and closed, and a small skin graft was placed at the base of the columella. The excess in this area of the cheek allowed significant advancement (to midline) without much Y component to the V-Y. D, Basal view. E, Four months postoperatively, the hair-bearing nature of the flap has allowed mustache growth to camouflage the area even further. (Case supplied by MRZ.)
This man presented with a basal cell carcinoma of the upper lip.

**Fig. 5C-12**  
A, The two-stage nasolabial flap is ideally suited for reconstruction of a defect resulting from excision of a basal cell carcinoma of the upper lip.  
B, The flap was based superiorly and made long enough and wide enough to resurface the lip defect.  
C, The flap was lifted just above the facial muscles. Deep dissection should be avoided to ensure that facial nerve branches are not divided.  
D, The flap was transposed medially to close the lip defect; the nasolabial defect was closed directly. A small Burow’s triangle was removed to eliminate the dog-ear skin excess.  
E, This photo shows how well this flap provides hair-bearing skin for an individual who wears a mustache. (Case courtesy Ian T. Jackson, MD.)
This patient had a basal cell carcinoma of the lower lip, which had been neglected and required an excision and reconstruction.

**Fig. 5C-13**  
A and B, This basal cell carcinoma of the lower lip was excised and reconstruction planned with an inferiorly based nasolabial flap. C-E, The flap was elevated above the facial muscles, taking care not to damage the underlying facial nerve branches. It was transposed to the lower lip and sutured into position. The donor defect was closed directly. F and G, A good result is shown: the mouth is symmetrical, the lip level is horizontal, and only slight pincushioning of the flap is present. The patient has no desire to have the latter corrected. (Case courtesy Ian T. Jackson, MD.)
This 66-year-old woman had a superficial defect within parts of the side wall and ala after Mohs excision of a basal cell carcinoma. Because of its simplicity, a one-stage, nonsubunit nasolabial flap was planned. The skin was transferred as a random flap. Available excess within the adjacent cheek would be rotated and advanced to resurface the combined sidewall and alar defect after placement of primary support along the nostril border.

**Fig. 5C-14** One-stage nasolabial flap. A, A significant defect of the left ala and sidewall was present after a Mohs excision. A pattern of the defect was designed lateral to the left nasolabial fold. Superiorly, a dog-ear excision was marked to create a space into which the cheek flap will advance. Another dog-ear excision was marked inferiorly along the nasolabial fold. B, The medial aspect of the cheek flap was incised along the nasolabial fold, and the cheek was undermined with 2 to 3 mm of subcutaneous fat. The cheek flap was advanced and fixed deeply along the nasofacial groove with permanent or slowly dissolving sutures to the underlying soft tissue. The one-stage nasolabial flap skin extension, which is an extension of the advancing cheek flap, can be cut out of the flap initially or from its excess leading edge after the cheek flap is fixed in its advanced position. The nasolabial fold donor incision was closed in layers. A primary cartilage graft was fixed to the underlying lining to support the nostril margin. C and D, The nasolabial extension was draped over the nostril margin without tension. The excess skin (of the inferior dog-ear) was excised and all incisions closed. Fine sutures can be placed from the deep surface of the flap into the underlying, ideal alar crease to reestablish its position if flap vascularity is good. E and F, The patient is shown postoperatively, without revision. There is mild nasolabial fold asymmetry. (Case courtesy Frederick J. Menick, MD.)
This elderly woman had a defect of more than 50% of the ala after Mohs excision of a basal cell carcinoma. The defect was entirely within the alar subunit. To better position peripheral flap border scars and to control trapdoor contraction within the subcutaneous fat on the undersurface of a two-stage transposition flap harvested from the nasolabial fold, the

Fig. 5C-15  Two-stage nasolabial flap. A, The defect was limited to the alar subunit. The nasal subunits were marked. An exact foil template of the contralateral normal right ala was drawn to abut the left nasolabial fold at the approximate level of the commissure. A distal dog-ear excision was marked. The proximal pedicle was tapered so that the final superior donor scar will be short and will not lie on the nasal surface or extend onto the cheek. B, A subunit of residual normal tissue within the left ala was excised. A primary conchal cartilage graft supported the nostril margin. The nasolabial flap was elevated distally with 2 mm of subcutaneous fat. The superior dissection was deepened to include perforators from the facial artery, based lateral to the ala. The inferior cheek dog-ear had not yet been excised. C, The nasolabial flap was inset with a single layer of fine suture. The cheek was closed in layers. D, Three weeks postoperatively, the medial and inferior inset had a good contour. The pedicle required division. E and F, The superior (above the dotted line) and lateral aspects of the inset were debulked at pedicle division. The flap skin was elevated with 2 mm of subcutaneous fat, and the underlying convex contour of the ala and the depth of the alar crease were re-created by soft tissue excision. Excess skin was trimmed and the flap inset.
The subunit principle was applied. Residual normal tissue within the left alar subunit was excised to alter the defect and permit resurfacing of the entire ala as a subunit, rather than patching the partial alar defect. The two-stage flap was vascularized through multiple vertical perforators that pass to the base of the flap pedicle through the underlying facial musculature from the facial artery. The pedicle will be divided at the second stage.

Fig. 5C-15  G and H, Final intraoperative scars were along the margin of the alar subunit and directly in the nasolabial fold. I and J, The patient is shown postoperatively, without revision. Alar contour is excellent. The donor scar is barely visible, although the nasolabial folds are asymmetrical. (Case courtesy Frederick J. Menick, MD.)
This 45-year-old man had a composite defect of the nose, lip, and cheek after Mohs excision. The full thickness of the right ala and sidewall was missing. Adjacent cheek, lip, and tip skin were absent. Soft tissue within the medial cheek and upper lip had been excised down to underlying bone. Because the nose sits on the cheek and lip in an exact position,
a stable platform had to be reestablished before formal nasal reconstruction. Skin from the nasolabial area can be rotated as a random extension of a cheek flap to resurface the medial cheek and upper lip. Once the skin is elevated, underlying fat is hinged over from the more lateral cheek to fill the soft tissue defect over the medial maxilla, like the page of a book. This soft tissue flap is based on subcutaneous perforators from the angular artery. Cheek skin is then rotated to resurface the medial cheek and upper lip defects. A stable soft tissue platform is re-created on which to build the nose at a later stage.

Fig. 5C-16  H and I, A superior nasolabial skin extension (a one-stage nasolabial flap) was cut out of the advancing cheek flap adjacent to the nasolabial fold, trimmed, and inset to resurface the future alar base. J and K, Once healed, the nasal defect was repaired with a three-stage folded forehead flap and delayed primary cartilage grafts on a stable midface lip and cheek platform. Postoperatively, after a staged reconstruction of the lip and cheek initially, and the nose secondarily, the complex three-dimensional contours of the nose, cheek, and lip are restored. The nose sits on a stable platform in the correct anteroposterior midface position. (Case courtesy Frederick J. Menick, MD.)
Pearls and Pitfalls

- The surgeon should not attempt to visualize the perforating vessels at the base of either the superiorly or inferiorly based nasolabial flap. Once the base of the flap is marked, dissection in this area should be minimized.
- The nasolabial fold, alar crease, and other important facial landmarks should be marked while the patient is awake and can animate the facial muscles. Once the patient is unconscious with muscles paralyzed, it will be difficult to find the natural creases. To the degree it is possible, it is important to leave the scar within the animation lines.
- If wide undermining of the cheek is performed for closure of the donor site, a small drain should be placed for at least 24 hours to avoid seroma formation.
- One disadvantage of island flaps such as the V-Y flap is possible pincushioning or edema of the flap for prolonged periods. The same is true after division and inset of a two-stage flap. At least 4 months should elapse before one considers debulking these flaps.
- Difficult-to-reconstruct areas, such as the commissure and the alar crease, should be preserved. Two-stage flaps are favored for these areas to bypass these natural transitions that are difficult to reproduce.
- Defects often require multiple flaps. The nasolabial flap can be used in combination with other regional flaps for lip and nasal reconstruction. One should not always try to have one flap do all things for all defects.

EXPERT COMMENTARY
Frederick J. Menick

Named flaps develop from clinical necessity. Common defects are identified, and available excess tissue is harvested that can be transferred on a reliable blood supply with predictable results and few complications.

Cheek skin lateral to the nasolabial fold is commonly used to resurface defects within the midface. The facial artery crosses the jawline and travels under the deep facial musculature lateral to the nasolabial fold toward the alar base, where its distal branch, the angular artery, continues toward the medial canthus. Multiple unnamed vertical perforators, primarily positioned above and below the lateral lip commissure, arise from the facial artery to perfuse the overlying skin. Based on the underlying perforator blood supply, excess tissue lateral to the nasolabial fold can be elevated as subcutaneously based island flaps, with or without a cutaneous random skin component as part of the pedicle. This medial cheek skin can be moved to resurface the lateral nose and upper and lower lip, most often as a transposition flap, and occasionally as a V-Y flap. Nasolabial skin can also be transferred as a random skin extension of an advancing cheek flap.
Advantages and Limitations
In mature patients a modest amount of skin is available lateral to the nasolabial fold; this can be harvested with minimal morbidity. Its color and texture match adjacent facial skin. If its donor scar lies directly within the nasolabial crease, late scarring is minimal.

It is common, even if the scar lies directly in the nasolabial fold, to pull the fold laterally. In all patients, the cheek is flattened, creating asymmetry. A contralateral excision of the opposite nasolabial fold can be performed secondarily to improve symmetry.

In adults, the available excess is limited to approximately 2 cm in width, whereas children have no excess tissue within the face, and no wrinkle in which to hide the scar. On the male face, hair-bearing skin of the beard is problematic. The surgeon risks transferring hair-bearing skin to a hairless recipient site, or vice versa. Although touted as a method for reconstructing a mustache, the follicle density of a transferred flap may not be similar to that of a normal upper lip, and the hair follicles are usually incorrectly oriented. Clinically, nasolabial flaps have a tendency to pincushion, bulging above the plane of adjacent normal skin.

The vascularity of all nasolabial flaps is reliable but not robust. They do not tolerate tension. Although occasionally recommended as a folded flap for covering and lining full-thickness alar defects, their bulk and modest blood supply make them a poor choice.

Anatomic Considerations
Skin from the nasolabial fold can be moved based on a random cutaneous blood supply or on the underlying subcutaneous perforators. The one-stage nasolabial flap can be used to resurface defects of the nasal sidewall and ala, and upper lip and nasal base/sill. Excess skin of the medial cheek, lateral to the nasolabial fold, is shifted as a random pattern extension of an advancing cheek flap. Unlike traditional local nasal flaps, which only redistribute residual nasal skin, this technique adds regional cheek skin to the surface of the nose. This minimizes the risk of distorting the adjacent mobile tip or nostril margin and allows the use of alar support grafts without risking collapse created by the tension of local nasal flaps.

The two-stage nasolabial flap transfers the same excess medial cheek skin, based on multiple perforating vessels that originate from the facial and angular arteries. The subcutaneous base of the flap is perfused by vessels that pass above and below the levator labia and muscle, and travel perpendicularly through the subcutaneous fat to the overlying skin. Although the proximal aspect of the skin flap may receive a random blood supply from its skin pedicle, the flap survives as a subcutaneous island flap. Because of this deep axial blood supply, a wide proximal skin pedicle is not necessary. Therefore this flap can be used even if the skin lateral to the ala is scarred or has been excised, as long as the underlying subcutaneous vascular base has not been significantly injured. The subcutaneous pedicle also permits easy transposition of the flap around its pivot point, without the constraint or twist necessitated by a wide skin pedicle.

Personal Experience and Insights
In my experience, nasolabial flaps are most effectively employed to resurface the nasal sidewall and ala, to reconstruct the upper lip and nasal base of a composite nose–lip–cheek defect, or as an island flap to resurface the lateral upper lip unit. But their limited size and reliable length, high risk of pincushioning, the donor site midface scar, and the advantages of other options—specifically, the forehead flap—limit their use to specific defects.
Recommendations

Technique
I perform most of my reconstructions with the patient under general anesthesia to avoid distorting the flap and recipient tissues. This also facilitates evaluating the three-dimensional contour and vascularity during flap elevation, and especially during suture closure, without the fluid bulk of local anesthetic injection and without the effects of epinephrine.

The regional units of the face are marked with ink initially. Exact templates of missing skin are designed based on the contralateral normal. It is difficult or impossible to make these decisions once the procedure is underway.

Bibliography With Key Annotations


The authors evaluated the effectiveness of extended nasolabial flaps and coronoidectomy in 47 randomly selected patients with histologically confirmed oral submucous fibrosis. All had an interincisal opening of less than 25 mm and were treated by bilateral release of fibrous bands, coronoidectomy or coronoidotomy, and extended grafting with a nasolabial flap. All had postoperative physiotherapy and were followed for 2 years. Their interincisal openings improved significantly from 14 mm (mean) to 41 mm (mean). The procedure was effective in managing patients with oral submucous fibrosis. The main disadvantage was extraoral scars.


The nasolabial skin is the donor site of choice for nasal ala reconstruction, especially when the patient does not want a forehead scar. Since its first description, the nasolabial flap has undergone several modifications. Its only drawback is that it is a two-stage procedure, and even when harvested on a subcutaneous pedicle, a second operation is required to restore an adequate nasal-cheek groove. The authors reported on their experience using the nasolabial perforator flap for one-stage nasal ala reconstruction in eight cases with good results, comparable to those obtained with the classic technique.


The authors presented a case report on a patient in whom they used a submental flap to reconstruct the oral commissure and partial defects involving the adjacent upper and lower lips. The same flap also provided lining for the buccal mucosa. This is a new application for this flap. The remaining resurfacing and bulk restoration for the upper and lower lips were completed with an adjacent nasolabial flap.


Although the increased application of microvascular free tissue transfer techniques for oral cavity reconstruction has decreased the need for local and regional flaps, a number of them are quite useful and should be considered for this purpose. Nasolabial flaps are versatile, easy to harvest, and can provide coverage for a variety of facial defects. The authors discussed a case in which they successfully used a bilateral pedicled flap to reconstruct the patient’s mandibular anterior alveolus after the wide excision of a squamous cell carcinoma. After 2½ years, there were no signs of recurrence.

Facial defects resulting from surgical excision of tumors can be difficult to repair. Skin grafts have a natural tendency to contract, may not take properly, and only cover superficial defects. Color mismatch can also be problematic. Regional flaps such as the median forehead flap are usually bulky, cannot cover a wide range of facial reconstruction, and usually require the donor area to be grafted. The authors utilized a nasolabial flap for facial reconstruction in 20 patients. This flap offers several advantages. It is a versatile, robust local flap that is easily elevated without delay. It can be superiorly based to reconstruct defects of the cheek, sidewall or dorsum of the nose, ala, columella, and the lower eyelid. Inferiorly based flaps are useful for reconstructing defects in the upper or lower lip and the anterior floor of the mouth. The flap can be turned over and used as a lining of the nose and lip. Indications, flap designs, technique, and complications were discussed.


Unoperated cleft lip and palate in an adult is typically the result of unfavorable economic and social circumstances. The authors treated a 65-year-old patient with bilateral complete cleft lip and palate. At the first stage, they performed a straight-line closure of the bilateral cleft lip, and a two-flap push-back palatoplasty with superiorly based lateral port control pharyngeal flap for the wide cleft palate. At the second stage, large, residual anterior palatal fistulas were closed using bilateral superiorly based (retrograde flow) full-thickness nasolabial island flaps.


The authors used a subcutaneous pedicled nasolabial flap for reconstruction in three patients. In the first case, a folded flap was utilized with a conchal cartilage strut sandwich. In the second case, only a folded flap was used. For the third case, the flap covered the outer surface of the ala, and a mucoperiosteal graft from the hard palate supplied the alar lining. In the first case, the cartilage strut was not sufficient to support the shape of the ala. Harvesting a sufficiently wide flap is important. In the second case, the folded flap had drawbacks, including the formation of a thick alar rim. The third case proved to be an excellent choice.


The authors shared their experience with superiorly and inferiorly based subcutaneous pedicled flaps for buccal mucosal defects in nine patients. They were elevated as skin islands, relying on a pedicle of subcutaneous tissue. Nine procedures were performed on small to moderate defects of the central portion of buccal mucosa. Four patients underwent superiorly based and five patients underwent inferiorly based “islanded” nasolabial flap reconstruction. All flaps were successful.


V-Y flaps are sometimes limited to only rotation or advancement. To overcome this drawback, the authors introduced a modified V-Y flap designed with a single laterally based pedicle for facial reconstruction in six patients. It was transferred through a transposition movement. The flap was reliable, robust, and could be moved easily with less tension. Defects were closed primarily along the nasolabial fold or preauricular crease. All patients had satisfactory functional and cosmetic outcomes.

The nasal dorsum is a good skin flap donor site for alar reconstructions because of its appropriate color, texture, and thickness. The authors studied the vascular anatomy of the nasal dorsum in five fresh-frozen latex-injected cadavers. Nasal septal branches from the superior labial arteries supplied the nasal tip. These arteries connected with lateral nasal branches (facial system) and dorsal nasal arteries (ophthalmic system) to form a consistent vascular network in the dorsal nasal superficial muscular aponeurotic system. This anatomy was the basis for safely raising distally based cutaneous flaps. The authors also reconstructed the nasal ala with an inferiorly based dorsal nasal flap in 14 patients. All flaps were successful.


Patients with multiple skin cancer defects present challenging reconstructions for plastic surgeons, often requiring more than one flap or skin graft. The authors performed an innovative reconstruction of simultaneous medial cheek and alar base nasal defects using a nasolabial flap. Concepts in nasal reconstruction were reviewed.


Although a variety of techniques have been proposed for the reconstruction of large defects of the lower lip, none is ideal. The authors presented their experience with reconstruction of defects of more than 75% of the transverse dimension of the lower lip using unilateral or bilateral subcutaneous nasolabial flaps. All patients had aesthetically acceptable results, complete oral competence, and normal speech. No complications were encountered. The authors discussed common alternate methods of lip reconstruction and their limitations. They concluded that this method of reconstruction is superior in appropriately selected patients; it is technically simple to perform and provides a functional and aesthetic result, with minimal donor site morbidity.


Total upper lip reconstruction is one of the most challenging procedures because of the size of the tissue and the loss of aesthetic subunits such as Cupid’s bow and the philtral columns. The authors presented a case of one-stage upper lip reconstruction with a bilateral reverse composite nasolabial flap.


In this article, the authors discussed the advantages of the nasolabial flap—both superiorly and inferiorly based variants—over microvascular free flaps and less-aesthetic skin grafts. They maintained that it offers an effective means of reconstructing facial and oral defects.


The authors performed lateral nasal artery pedicled nasolabial flaps in 12 patients with large nasal tip and alar defects. Lateral nasal artery pedicled nasolabial flaps were used in nine cases and island flaps in three. In five patients, cartilage grafts were used for alar rim support, and the distal end of the nasolabial flap was thinned and folded to repair the nasal lining. Donor sites were closed primarily. There was mild venous stasis at the distal end of three island flaps that resolved without intervention. All flaps survived. Five flaps were revisions that were performed 6 to 15 months postoperatively because of mild swelling at the pedicles of skin flaps. The follow-up period was 8 to 24 months. All patients had satisfactory nasal appearance, flap texture and color, and ventilatory function. No obvious scar was found at donor sites.

The authors were the first to use the Hughes procedure (tarsoconjunctival flap) to reconstruct a full-thickness squamous cell carcinoma of the lower left eyelid. The patient was a 54-year-old man. The procedure was combined with a subcutaneously based nasolabial flap for skin coverage.


The authors reviewed major aspects and subtle nuances of nasal reconstruction. The nasal lining, support, skin coverage, local nasal flaps, the nasolabial flap, and the paramedian forehead flap were discussed, as well as the subunit versus defect-only reconstruction controversy. It was confirmed that applying a variety of options for each defect provided the best outcome. The authors also presented a novel approach to full-thickness skin grafting, recommended for lower third reconstruction. Postoperative care, including dermabrasion, skin care, and counseling, were emphasized.


The authors reviewed a series of 80 nasolabial flaps, 38 of which were used for partial or complete tip reconstruction. Three complications occurred, with one resulting in complete flap loss. The nasolabial flap is a versatile, pedicled flap that, with proper modifications, careful patient selection, and appropriate postoperative management, is an excellent option for lateral nasal wall, ala, columella, and intraoral reconstruction.
**ANATOMIC LANDMARKS**

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>The temporoparietal fascia flap bounded superiorly by the superior temporal fusion line, anteriorly by the orbital rim, inferiorly by the supramastoid crest and the zygomatic arch, and posteriorly by the temporal fossa of the parietal bone.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>14 × 10 cm.</td>
</tr>
<tr>
<td>Composition</td>
<td>Fascial, fasciocutaneous, type A.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Superficial temporal artery.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td>Sensory: The auricular temporal nerve (mandibular branch of the trigeminal nerve).</td>
</tr>
</tbody>
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Section 5D

HEAD AND NECK

Temporoparietal Fascia Flap

CLINICAL APPLICATIONS

Regional Use
- Ear
- Orbit
- Anterior cranial base
- Upper face

Distant Use
- Face
- Contralateral ear
- Upper extremity
- Lower extremity

Specialized Use
- Scalp
- Ear
- Eyebrow
- Mustache
ANATOMY OF THE TEMPOROPARIETAL FASCIA FLAP

A

Bony anatomy

Parietal bone
Temporal bone
Frontal bone
Sphenoid bone
Zygomatic bone

Temporoparietal fascia

Temporalis muscle (under temporoparietal fascia)
Occipitalis muscle
Galea aponeurotica

Muscle and fascial anatomy

Temporoparietal fascia

Frontalis muscle

B

C

Neurovascular anatomy

Superficial temporal artery
Frontal branch of facial nerve
Zygomatico-temporal branch of facial nerve
Parotid gland

Dominant pedicle: Superficial temporal artery

Fig. 5D-1
ANATOMY

Landmarks  The temporoparietal fascia flap occupies the temporal fossa, which is bounded superiorly by the superior temporal fusion line (which marks the origin of the temporalis muscle), anteriorly by the lateral orbital rim, and inferiorly by the zygomatic arch and supramastoid crest. Fascia can be extended posteriorly beyond the temporalis muscle, though not across the midline.

Composition  Fascial, fasciocutaneous.
Size  $14 \times 10$ cm.

Arterial Anatomy

Dominant Pedicle  *Superficial temporal artery*

Regional Source  External carotid artery.

Length  4 cm.

Diameter  2 mm.

Location  Superficial temporal artery originates posterior to the vertical ramus of the mandible and extends over the zygomatic process of the temporal bone. It is located anterior and deep to the superficial temporal vein and courses superiorly on the surface of the superficial temporal fascia. Superior to the zygomatic arch a deep branch, the middle temporal artery, enters the temporalis muscle; 2 to 4 cm superior to the zygomatic arch, the vessel divides into its terminal branches. The frontal branch courses anteriorly and supplies the frontalis muscle. The parietal branches are variable and supply the parietal scalp to the vertex and posteriorly to anastomose with terminal branches of the occipital vessel.

Venous Anatomy

The superficial temporal vein runs with the artery generally but can be found as far as 3 cm away in some patients. It is located anterior and superficial to the artery immediately below the subdermal fat. Drainage from the vein joins the retromandibular vein. At the level of the zygoma the vein is approximately 2 to 3 mm in size.

Nerve Supply

Sensory  The auriculotemporal nerve (mandibular branch of the trigeminal nerve).
Vascular Anatomy of the Temporoparietal Fascia Flap

Fig. 5D-2

Dominant pedicle: Superficial temporal artery (D)
**FLAP HARVEST**

**Design and Markings**
The flap is exposed through a T, Y, or zigzag incision, depending on the amount of fascia required and the surgeon’s preference.

![Incision](image)

**Fig. 5D-3** Once the superficial temporal artery’s course is determined by handheld Doppler, a zigzag incision is planned in the hair-bearing area to expose the flap and give the best cosmesis.

**Patient Positioning**
The patient is placed in a supine position.

**GUIDE TO FLAP DISSECTION**
Dissection starts in the preauricular area with identification of the superficial temporal artery, vein, and the auriculotemporal nerve. A handheld Doppler probe can be used initially to help locate these vessels and to map them out on the scalp.

![Initial dissection](image)

**Fig. 5D-4**
Dissection then proceeds superiorly in a subcutaneous plane. The surgeon should attempt to stay just deep to the hair follicles to prevent injury to the fascia. Hemostasis is critical during this procedure so the layers of the temporal fascia can be easily seen and dissected. After the skin flaps are elevated, the superficial temporal fascia can be visualized, as well as the associated neurovascular structures. The size of the desired flap is then marked, tapering the design down to its pedicle.

If desired, two layers of fascia can be harvested, both the superficial temporal fascia and the deep temporal fascia, separately if needed, or as a combined unit, depending on the reconstructive need.
The periphery of the flap is then incised and the flap is elevated. The superficial fascia can be separated from the deep temporal fascia, entering a loose areolar avascular space. As one nears the zygomatic process, care must be taken to avoid injury to the frontal branch of the facial nerve. As the zygomatic arch is reached and the flap is reflected, the middle temporal branch to the deep fascia can be seen.

If only the superficial temporal fascia is being taken, this vessel is ligated. If the deep fascia is to be taken as well, dissection proceeds to the perimeter of the deep fascia, which is then elevated off the underlying temporal muscle. This is the same dissection that one would start if the flaps were to be maintained in a conjoined fashion. As the deep fascia is dissected inferiorly, there is some attachment to the zygoma that must be carefully divided. The middle temporal artery can be seen on the deep surface of the deep fascia, and further dissection proximally will allow the two fascial flaps to remain attached, as the superficial temporal artery and superficial temporal vein can be dissected further.

**FLAP VARIANTS**

- Fasciocutaneous (hair-bearing) flap
- Free flap
**Fasciocutaneous (Hair-Bearing) Flap**

The temporoparietal fascial flap can be carried with overlying scalp and hair-bearing skin. This is particularly valuable for reconstruction that requires hair-bearing tissues at the eyebrow, mustache, or other areas of facial hair in men. It is helpful when designing these flaps to use a Doppler probe to map the branches of the superficial temporal artery so the flaps can be placed directly over one of these branches. The surgeon must look at the hair follicles and the direction of hair growth so that after rotation of the flap, the hair will grow in the correct direction (see Section 5B, Fig. 5B-14).

**Free Flap**

The temporoparietal fascia is valuable. This thin vascularized fascial tissue can be used in reconstructions throughout the body. When it is not available as a local flap, the contralateral temporoparietal fascia can be transferred as a free tissue transfer for ear reconstruction (see Fig. 5D-8). This is also a favored flap in tendon reconstruction of the hand and the foot because of its thin coverage and its ability to allow tendon gliding within it.

**ARC OF ROTATION**

The temporoparietal fascial flap easily rotates anteriorly for coverage of the forehead, orbit, and cheek. This is a valuable flap for dural and cranial base reconstruction as well as orbital reconstruction. This is the flap of choice to be used in ear reconstruction, because the flap rotates toward its pedicle, which is at the ear. The ultimate arc is limited by the viability of extensions of the flap, which do not reasonably go beyond the temporal fusion line superiority and the midline posteriorly.

![Diagram of Superficial Temporal Artery and Arc to Middle Third of Face](image)
FLAP TRANSFER
The flap is transferred as a transposition flap and is either passed through a subcutaneous tunnel or is directly transferred to the defect. If skin is not carried with the flap, skin grafting is often required.

FLAP INSET
For a pedicle flap, the pedicle must not be kinked or compressed in any way if it is to be tunneled. The fascial component of the flap holds suture well and secures the flap in position. When temporoparietal fascia is used as a free flap, it is important to inset and secure the fascia before microscopic anastomosis is performed to prevent kinking and torsion of the pedicle.

DONOR SITE CLOSURE
Closure of the donor site should be planned so that a primary closure can be performed. In most cases, when skin is not taken with the flap, there is no problem closing the skin. One must avoid cauterization of hair follicles and undue tension on the closure to prevent healing problems and alopecia.
CLINICAL APPLICATIONS
This 62-year-old man had a history of resection of a brain malignancy and a metallic cranioplasty for reconstruction 10 years earlier. He had undergone postoperative irradiation of the scalp and presented with exposure of his cranioplasty, but no evidence of recurrence of cancer. The neurosurgeon wanted to preserve the cranioplasty if at all possible.

Fig. 5D-6  A, Preoperative view of the exposed hardware. There was no evidence of cellulitis or deep infection. The skin was thin and atrophic, consistent with his history of irradiation. B, This radiograph shows the extent of the metallic cranioplasty. C, The location of the prosthesis relative to the open wound. The plan was a wound debridement and removal of a small portion of the cranioplasty that was placing pressure on the overlying skin. Coverage with a rotational temporoparietal fascial flap was felt to be necessary to promote uncomplicated healing. X’s mark the location of the superficial temporal artery.
The temporoparietal fascial flap was elevated and the modified metal cranioplasty noted. The turnover flap easily covered the prosthesis. The deep temporal fascia was left in situ. Although a skin graft was initially planned, primary closure was possible. At the 2-month follow-up, the wound was healed and the edge of the prosthesis was not palpable. (Case supplied by MRZ.)
This child presented with traumatic loss of the upper third of the ear. Her parents requested reconstruction of the ear.

**Fig. 5D-7**  
A, Through a vertical temporal incision, the temporalis fascia was elevated, based inferiorly. It is important in such cases that a generous amount of fascia be elevated, because it is always possible to sacrifice any excess during the reconstructive process. The scalp wound was closed with suction drainage. B, A portion of costal cartilage was harvested and carved to the dimensions of the missing portion of the ear, together with the three-dimensional anatomy. This was sutured to the remaining ear cartilage with nonabsorbable sutures. The fascial flap, which was tunneled under the bridge of skin beneath the donor site and ear, was placed over the ear cartilage graft. C, The temporalis fascia flap was trimmed and then used to cover the cartilage graft. The skin of the edge of the ear defect was gently elevated and a temporalis fascia flap sutured into position with the skin of the ear overlapping the sutured area.
Fig. 5D-7  D, A thick split-thickness skin graft was harvested and placed over the reconstruction and sutured into position. Several small punctures were made with a No. 11 blade to allow drainage of blood from under the graft. The temporal area was drained with a small suction drain and a light dressing was applied. E and F, At the 6-month follow-up, the ear is slightly short in the vertical dimension, but the contours of the ear are satisfactory. (Case courtesy Ian T. Jackson, MD.)
This 24-year-old woman had been assaulted with a shotgun and sustained a wound encompassing the left ear, mastoid, and significant overlying skin. Her immediate care involved a scalp flap and back grafting (see Section 5B). She presented for delayed total ear reconstruction. Because a temporoparietal fascia flap was not available as a result of the gunshot wound, a free temporoparietal fascia flap was harvested from the contralateral side and used for reconstruction.

Fig. 5D-8  A, The defect at initial presentation. B, The patient was treated with a rotational scalp flap and grafting of the scalp donor. She did well and presented 2 years after the scalp flap for ear reconstruction. C, A rib cartilage construct was planned, but no local tissues were available for coverage. D, A free temporoparietal fascia flap was planned from the uninjured contralateral side, initially covering a tissue expander.
Fig. 5D-8  

**E**, The free flap after harvest. **F**, The flap was inset over a tissue expander and skin grafted. The area was grafted, and 3 months later the cartilage construct was placed. **G**, The cartilage construct, based on a template of the normal ear on the right. **H**, The patient is seen 9 months after placement of the cartilage with good ear definition. The patient is seen undergoing tissue expansion of her scalp and will undergo reconstruction of the area of alopecia. (Case supplied by MRZ.)
This patient developed radiation necrosis after enucleation and irradiation of the right eye for recurrent melanoma.

**Fig. 5D-9**  
A. The patient is seen preoperatively.  
B. A temporoparietal fasciocutaneous flap was designed.  
C. The flap was exposed via a classic T-shaped incision and raised in the manner described.
Fig. 5D-9  D-F, The deep lamina of the flap is also shown. Once the flap was elevated, it was skin grafted in situ, and the skin-grafted temporoparietal fascia flap was tunneled into the orbit through a lateral orbitotomy. G, The patient is shown postoperatively. (Case courtesy Julian J. Pribaz, MD.)
A temporoparietal fasciocutaneous flap was planned to reconstruct this patient's traumatic loss of his right eyebrow.

Fig. 5D-10  A, The superficial temporal vessels were identified by Doppler probe. B and C, The fasciocutaneous flap was raised as an island at the distal part of this flap and then tunneled across into the eyebrow region. The flap was very robust. D, Hair growth was abundant from this flap, and regular trimming is required. Care should be taken to avoid injury to the frontal branches of the facial nerve with a superficial dissection to the eyebrow region. (Case courtesy Julian J. Pribaz, MD.)
This man presented with a subtotal ear defect involving the upper two thirds of his ear.

**Fig. 5D-11**  
A and B, A zigzag approach was designed for harvesting the temporoparietal fascia flap. The cartilaginous construct in this older adult was semiossified and therefore difficult to carve.  
C, Some postauricular skin was used to provide posterior coverage and allow projection of the constructed ear.  
D, The temporoparietal fascial flap covered the anterior and upper posterior aspect of the construct, and a full-thickness skin graft was placed over this.  
E and F, The postoperative result is shown. (Case courtesy Julian J. Pribaz, MD.)
This woman had a burn injury on the dorsum of the hand, and a temporoparietal fascia flap was planned.

Fig. 5D-12  A, The patient is shown preoperatively with the flap design. B and C, A free temporoparietal fascial flap was elevated and transferred to the hand, anastomosing the superficial temporal vessels to the radial vessels. D, A full-thickness skin graft was then applied. E, The postoperative result is shown. A thin, pliable reconstruction with good aesthetics was created. (Case courtesy Julian J. Pribaz, MD.)
**Pearls and Pitfalls**

- The scalp is shaved and the entire vascular tree is marked with the aid of a Doppler probe before the flap is planned. To ensure the best vascularity, the flap is centered over one of the branches.
- Injury of the hair follicles must be avoided during dissection to prevent alopecia.
- Early identification and sparing of the auricular temporal nerve will prevent some common postoperative problems such as numbness and sensitivity. The use of a nerve stimulator is sometimes helpful to prevent injury to the frontal branch of the facial nerve.
- In cases of hemifacial microsomia and congenital deformities of the head, the anatomy of the superficial temporal system as well as the temporal fascia may be abnormal and not usable for local flap reconstruction.
- Hemostasis is essential if both the superficial temporal and the deep temporal fascia are required as separate leaves of the flap. Once the tissues are blood stained, it is hard to dissect them.
- When more fascia is needed than 14 by 10 cm, one should consider an alternate donor site. Extensions of this flap have poor vascularity beyond the territory described.
- Hair transplantation techniques have largely replaced hair-bearing flaps for mustache and eyebrow reconstruction.

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**EXPERT COMMENTARY**  
Julian J. Pribaz

**Indications**

The temporoparietal fasciocutaneous flap is a very useful and hardy flap that can be used to reconstruct a variety of local and distant defects. The flap is based on the rich vascularity coming from the superficial temporal vessels and its arborizing branches. It is very versatile and may be used as a vascularized fascial flap (both locally and as a free flap distally) and as a fasciocutaneous flap to reconstruct hair-bearing regions of the face.

**Advantages and Limitations**

The flap is very well vascularized, thin, and pliable. However, the size is limited and as mentioned in the text, it is limited to approximately 14 by 10 cm. The fact that the overlying skin is hair-bearing is an advantage for repairing hair-bearing defects, but if one desires a non-hair-bearing fasciocutaneous flap, this flap is not suitable. The flap has the added advantage that the temporal fascia is laminated, and separate layers can be dissected and fanned out to increase the surface area of coverage. Also, the inherent lamination of the temporoparietal flap can be useful when this flap is used to reconstruct the dorsum of the hand, especially after burns, where tendons can be inserted between the two layers of this well-vascularized flap, to assist with tendon gliding.
Anatomic Considerations
The anatomy of this flap is well described in the chapter. In the harvesting of this flap, great care is needed to prevent injury to the hair follicles, which are immediately above the fascia, as well as the flap blood supply, which is on the superficial aspect of the flap.

Personal Experience and Insights
The temporoparietal fascia flap has been used quite extensively. As a local fasciocutaneous pedicle flap, it has been used to reconstruct the eyebrow. The problem is that an eyebrow reconstructed in this fashion will grow hair much more rapidly than the normal contralateral side requiring repeated trimming (see Fig. 5D-10). For restoration of the mustache and upper beard area in men, this flap has been used as a large bipedicle flap as a two-stage procedure. This may be indicated especially in a burn patient. The flap is divided and inset after about 3 weeks. However, the hair growth that occurs is profuse and is not of the same consistency and distribution of normal mustache hair.

I have used this as a fascial flap in orbital reconstruction, especially in a contracted or radionecrotic orbital defect that can arise after enucleation and radiation (see Fig. 5D-10). When used in this setting, the flap is skin grafted; it is preferable to apply the skin graft to the flap before transfer into the orbit, since it is very difficult to inset a graft within the orbital cavity. It is much simpler to do this with the flap dissected out before transfer.

When the flap is used for ear construction (see Fig. 5D-11), the possibility of expanding the reach of the flap by separating the deep and superficial layers can be a very useful adjunct to provide maximal coverage of the cartilaginous constructs.

Recommendations
The approach to harvest the flap, although classically described as a T-shaped or Y-shaped scar, may in fact leave a visible scar, because some alopecia can occur along the margins. It has been found that doing this as a zigzag-type incision provides better camouflage at the donor site. The vessels are identified by Doppler ultrasound, and the dissection commences distally, away from where the main identified vessels are located. The dissection occurs just deep to the fatty tissue surrounding the hair follicles. Dissection with needle-tip cautery set at 12 to 15 cm can facilitate the dissection. When used as a free flap, the pedicle is dissected proximally to the parotid, where the superficial temporal artery and vein are at least 2 mm in diameter.

Bibliography With Key Annotations

Anophthalmic socket reconstruction is a challenging problem in plastic surgery. The authors had described a prefabricated superficial temporal fascia island flap and used this technique in more than 50 enucleation patients with severe socket contraction, ending in excellent or good results for 28 years (Altindas-1 procedure). However, the flap was not suitable for exenteration patients with complete eyelid loss. The technique was modified and used in exenteration patients (Altindas-2 procedure). In this two-stage procedure, the temporoparietal fascia is prefabricated with a full-thickness skin graft from the retroauricular area, and a strip of scalp is preserved at the middle of the flap. The flap is transferred to the orbit through a subcutaneous tunnel at the second stage. The prefabricated flap is used for the reconstruction of eyelids and periorbital skin; a scalp island is used for the reconstruction of lid margins and eyelashes; and the neighboring bare temporoparietal fascia is used for the augmentation of the
periorbital soft tissues. The orbital lining is elevated as a centrally based skin flap and used for the reconstruction of the eye socket, fornices, and posterior lining of the eyelids. The technique was used successfully in five total exenteration patients with complete eyelid loss. In one patient, the ipsilateral temporal island flap had been used previously, so the flap was prepared from the contralateral site and transferred to the anophthalmic orbit as a free flap 5 weeks later. With this procedure, it is possible to reconstruct a stable eye socket that is suitable for ocular prosthesis, upper and lower fornices, periorbital skin with good color matching, naturally looking eyelids with eyelashes and lid margins, and medial and lateral canthal areas. It is also possible to improve periorbital soft tissue atrophy, which is an important problem in patients who had radiotherapy previously. Free transfer of the flap provides a new solution for the reconstruction of cases that were operated previously.


After a brief review of the history of ear reconstruction in general and microtia specifically, the author discussed issues related to the transition in popularity from techniques involving three or more stages (Tanzer and Brent) to the current popularity of two-stage procedures (Nagata, Firmin, and Park). Each of the popular procedures was considered in relation to timing of the reconstruction, procedure planning, and how both the soft tissues and framework construction are handled in each of the stages. The most significant differences included whether the autogenous cartilage framework is constructed with or without the tragal construct (for the lobular-type microtia), whether the lobule is rotated in the first-stage reconstruction, whether an additional cartilage block is placed behind the framework for added ear projection, and how that added block is covered (choice of fascia flap and skin graft). Each of the techniques has to be varied in reconstruction of auricular dystopia in light of the associated skeletal and soft tissue hypoplasia. The author demonstrated that although there may be significant advantages to the two-stage reconstructions of Nagata and Firmin, some may feel that the larger amount of cartilage harvested, the later optimal age for beginning the reconstruction, the additional scalp scars engendered by using the temporoparietal fascia flap in the second-stage elevation of the framework, and even the exchange of lobule tissue (and ability to later pierce ears) to obtain better coverage of the concha and tragus are unacceptable. Having gained experience with each of the varied approaches and having modified them when unusual variations in deformities have required it, the author discussed his current preferences. Clearly, the author thinks that there may be significant advantages to delaying the reconstruction to age 10 years or older, yet experience gained over the past 25 years would seem to indicate that as in all other aspects of plastic and reconstructive surgery, one must never be wed to a single approach, and experience and flexibility are essential in obtaining the optimal outcome in all variations of the deformity.


Microsurgical transfer of the superficial and deep temporal fascia based on the superficial temporal vessels has been documented. This article analyzed the functional recovery when each layer of this fascial flap is placed on either side of reconstructed or repaired tendons, to recreate a gliding environment. This fascial flap also provided a thin, pliable vascular cover in selected defects of the extremities. Six patients (four male and two female) with tendon loss and skin scarring of the hand (three dorsum, one palmar, and one distal forearm) and posttraumatic scarring of the ankle with tendoachilles shortening (one patient) underwent this procedure. No flap loss was witnessed. Good overall functional recovery and tendon excursion were observed. Partial graft loss was observed in two patients.


Temporoparietal fascial grafts have been used for both nasal and facial contouring, for vascularized tissue coverage, and to augment the nose and lip. The temporoparietal fascial graft is easily neovascularized and provides thin, broad, pliable, adequate coverage, contour, and bulk on the cartilage dorsum of the nose, and creates an inconspicuous donor site. A 23-year-old woman motorcyclist had an accident with one angular laceration wound on the dorsum of the nose. There was intermittent discharge in the dorsal nose 2 weeks after primary repair. Six months later, open-tip rhinoplasty was performed...
to the recurrent fistula of the nose dorsum. There were two fistulous orifices and one fibrotic cavity with hair ingrowth. After replacement of the rolled temporoparietal fascia, external nasal splinting was applied to mold the shape for 1 week. There was no graft exposure or recurrent infection. The procedure is a useful method to eliminate inflammatory sequelae. The smooth nasal dorsum skin was regained with adequate nasal projection.


The temporoparietal fascial (TPF) flap is a thin, pliable, and well-vascularized flap that is ideal for reconstructing hand defects. However, conventionally harvested flaps result in a large scar over the temporal fossa, which may be problematic in patients with male pattern baldness. The authors described an endoscopic technique for harvesting the TPF flap through a 4 cm preauricular incision to reduce donor site morbidity. Five TPF flaps were used to cover hand wounds. Three of the flaps were successful, and there were no injuries to the frontal branch of the facial nerve in this series. Endoscopic harvest of the TPF flap is an ideal solution for covering medium-sized hand defects without potentially prominent scars in the temporal area.


Although vascularized calvarial bone grafts were originally explored for use in reconstruction of midface hypoplasia defects, they offer significant value in application to oncologic reconstruction of the midface. The authors reviewed eight cases of midface reconstruction using vascularized calvarial grafts to illustrate the versatility and dependability of these flaps. Adequate bony and soft tissue contours were achieved with no clinical evidence of bone graft resorption. No immediate postoperative complications including infection and hematoma or seroma formation were noted. One patient experienced delayed sinusitis from a blocked duct.


Fourteen temporoparietal fascial free flaps were used for correction of first web space atrophy from ulnar nerve palsy in 13 patients; 10 had sustained ulnar nerve injuries and three had leprosy. General anesthesia was used in 12 patients; one leprosy patient with bilateral ulnar nerve palsy had local anesthesia and a brachial block for harvest of bilateral free flaps and recipient site preparation, respectively. Follow-up ranged from 4 to 64 months. Postoperative results were satisfactory, and there was no resorption of the free flaps. The consistency of the augmented first web space was soft and had a compressible, natural feel. The size of the flap was more than enough for augmentation of the first web space, and donor site morbidity was minimal and accepted by all patients. The authors concluded that the temporoparietal fascial free flap is an ideal autologous tissue for correction of first web space atrophy.


Prefabricated flaps allow transfer of a selected tissue as an axial flap to enhance the vascular supply of a random skin flap. The prefabricated expanded flap is an effective technique for reconstruction of facial defects in selected patients.


This article described the use of the temporoparietal osteofascial flap (TOF) for reconstruction of bony defects in the midface and mandible. The authors reviewed the demographics, causes, indications, surgical technique, radiographic evaluation, and final outcome of 11 patients with upper or lower jaw defects who underwent reconstruction using the TOF between 1994 and 1999. The TOF was used to reconstruct a defect of the mandible in seven patients, the hard palate in two patients, the maxilla in one patient, and the zygoma in one patient. This vascularized calvarial bone flap can be used for reconstruction of small to medium-sized defects of the maxilla and lateral mandible with good functional and cosmetic results. It can be performed without special microvascular expertise and with minimal donor site morbidity. A full-thickness bone flap can support osteointegrated dental implants.

The authors reviewed the charts of six consecutive patients who underwent reconstruction of intraoral defects using the pedicled temporoparietal galeal flap. All of the defects were in the posterior oral cavity and oropharynx. After resection of the oral cancer, the temporoparietal galeal flap, based on the superficial temporal vessels, was raised and transposed to the mouth through a tunnel under the zygomatic arch. The oral defect was repaired, and no skin graft was applied over the flap. There were no flap losses, and the reconstructive goal was achieved in all cases. The patients’ deglutition and phonation abilities were restored, and the donor site scars were well hidden by hair growth.


A free temporoparietal fascial flap with a split-thickness skin graft was used to cover a large palmar forearm wound in a patient whose hand had been replanted 21 days earlier after traumatic amputation at the distal forearm level. At 39 months’ follow-up, the patient had achieved an excellent cosmetic and functional result, with no alopecia or facial nerve injury. This flap is advantageous for coverage of wounds that require a large amount of thin, pliable tissue, and the donor site scar is concealed.


A retrospective review of the senior author’s personal database over a 6-year period of cases in which a temporoparietal fascia (TPF) flap was used. Sixty-five TPF flaps were used for reconstructions of the ear and lateral skull base. Indications for surgery included cholesteatoma, chronic otitis media, cerebrospinal fluid fistula, and meningoencephalocele. All mastoid cases were epithelialized at 6 weeks. Complications encountered and discussed were a mastoid-cutaneous fistula, mastoid hematoma, and canal stenosis (5%; n = 3). The authors concluded that with appropriate technique and indications, the TPF flap is an important reconstructive option after ear and lateral skull base surgery.


The authors evaluated the conspicuousness of the temporal scar caused by two incision patterns after harvesting the temporoparietal fascial flap: a straight incision and a zigzag incision. The 27 scars of 27 patients were examined; 15 patients had a straight incision and 12 had a zigzag incision. This study showed that the zigzag incision resulted in more conspicuous scars than the straight incision, and this effect was more evident in younger individuals than in older ones, at least among Japanese patients. In a comparison of older patients and younger patients, irrespective of the skin incision patterns, the scars were substantially more conspicuous in younger patients. A simple, short incision is preferred when harvesting the temporoparietal fascial flap, and more careful management is required for young patients.
ANATOMIC LANDMARKS

Landmarks  Fan-shaped muscle that occupies the temporal fossa and extends onto the lateral skull. It can be palpated above the zygomatic arch and extends under the zygomatic arch to the mandible.

Size  10 × 20 cm.

Origin  Temporal fossa and temporal fascia.

Insertion  Anterior coronoid process and anterior ramus of the mandible.

Function  One of the muscles of mastication; assists in mandibular retraction and elevation.

Composition  Muscle.

Flap Type  Type III.

Dominant Pedicles  Anterior deep temporal artery and the posterior deep temporal artery.

Minor Pedicle  Middle temporal artery branches.

Nerve Supply  Motor: Anterior and posterior deep temporal nerves (fifth cranial nerve).
Section 5E

HEAD AND NECK

Temporalis Flap

CLINICAL APPLICATIONS

Regional Use
- Orbit
- Maxilla
- Mandible

Specialized Use
- Facial reanimation
**ANATOMY OF THE TEMPORALIS FLAP**

**A**

Muscle and bony anatomy

**B**

Vascular anatomy

**Fig. 5E-1**

**Dominant pedicles:** Anterior deep temporal artery; posterior deep temporal artery

**Minor pedicle:** Branches of middle temporal artery
ANATOMY

Landmarks
Fan-shaped muscle that occupies the temporal fossa. The muscle can be palpated above the zygomatic arch when the teeth are clenched. Below the arch, the muscle extends to the mandible and is not palpable.

Composition
Muscle. Although the overlying skin could be carried anatomically with the flap, it is rarely needed and would create donor site morbidity.

Size
10 × 20 cm.

Origin
Temporal fossa and temporal fascia.

Insertion
Anterior coronoid process and anterior ramus of the mandible.

Function
The temporalis is a muscle of mastication; it assists in mandibular retraction and elevation.

Arterial Anatomy (Type III)

Dominant Pedicle  Anterior deep temporal artery

REGIONAL SOURCE Maxillary artery.
LENGTH 2 cm.
DIAMETER 1 mm.
LOCATION Deep to the muscle at the level of the zygomatic arch.

Dominant Pedicle  Posterior deep temporal artery

REGIONAL SOURCE Maxillary artery.
LENGTH 2 cm.
DIAMETER 1 mm.
LOCATION Deep to the muscle at the level of the zygomatic arch.

Minor Pedicle  Branches of the middle temporal artery

REGIONAL SOURCE Superficial temporal artery.
LENGTH 1 cm.
DIAMETER 0.5 mm.
LOCATION Superficial surface of the middle third of the muscle.

Venous Anatomy
Paired venae comitantes accompany the named arteries.

Nerve Supply

Motor
Fifth cranial nerve, mandibular division. The deep temporal branches of the anterior trunk of the nerve enter the posterior-superior portion of the muscle.
**Vascular Anatomy of the Temporalis Flap**

**Fig. 5E-2**

**Dominant pedicles:** Anterior deep temporal artery \((D_1)\); posterior deep temporal artery \((D_2)\)

**Minor pedicle:** Branches of middle temporal artery \((m)\)
FLAP HARVEST

Design and Markings
An incision that overlies the temporal muscle is placed within the hair-bearing area to camouflage the scar. This curvilinear incision will run down to the preauricular area for best cosmesis and exposure of the zygomatic arch. A zigzag incision may also be used to better conceal the scar.

![Marking for incision for flap elevation](image)

Patient Positioning
The flap is usually elevated with the patient in a supine position with the head turned, depending on the needs of the case. The flap could also be harvested with the patient in a lateral decubitus position.
GUIDE TO FLAP DISSECTION
The origin of the muscle from the temporal bone is taken down sharply or with a Bovie cautery, and the muscle is easily dissected off the temporal fossa with a periosteal elevator. There is no danger to the pedicle until dissection reaches the level of the zygomatic arch. At this point, the motor nerves and vascular pedicle can be identified on the deep surface of the muscle. For most indications, no further dissection is required, and no further skeletonization of the pedicle or nerves is needed.

FLAP VARIANTS
- Functional muscle transfer
- Segmental transposition flap
- Vascularized bone flap
Functional Muscle Transfer
The temporalis muscle is an option for reanimation of the face, particularly reanimation of the mouth, eye, and eyelid. Exposure is begun as described previously with identification of the superficial surface of the muscle. The central third of the muscle can be taken to minimize bulk and ease rotation of the muscle into proper position. Extensions of fascia can be taken to help extend the muscle for insertion into the commissure.

A second variant of this flap involves removal of the insertion of the temporalis muscle from the coronoid process and rotation toward the commissure with insertion. When the flap is used for reanimation of the eyelid, smaller segments of temporalis muscle can be transposed to the lower eyelid with extensions of fascia to act as both a static and functional sling.

Segmental Transposition Flap
The muscle can be split into an anterior and a posterior half or can be harvested as a central third, as described previously. It can be helpful to divide the muscle when the reconstruction involves areas that cannot be covered by a single flap. Some degree of muscle splitting can also be used to attempt to animate different portions of the lip or periorbital area.

Vascularized Bone Flap
Although connections are present between the muscle and the temporal bone, such combined myoosseous flaps are rarely used, because free calvarial grafts covered by temporalis muscle work just as well and provide a better donor site for bone harvest.
**ARC OF ROTATION**
When the flap is elevated and the zygomatic arch is the point of rotation, coverage of the orbit, upper cheek, and maxilla is possible. Extension of the rotation of the flap can be attained by removal of the central section of the zygomatic arch. For facial reanimation, the arc of rotation for periorbital or for smile reanimation can be extended by the use of fascia, such as temporoparietal fascia or fascia lata. This allows comfortable reach of the muscle and proper tensioning for a functional result.

**Fig. 5E-6**

Arc to orbit

Arc to midface

Extended arc to lower third of face (zygomatic arch divided)
FLAP TRANSFER
For orbital and skull-base defects, the flap is transferred by transposition. This can be through the muscle bed or anteromedially into the orbit.

For reconstruction in the palate and mandible, the muscle is transposed over the zygomatic arch and can rotate 180 degrees or turn over on itself. Passage of the muscle underneath the arch without arch removal is not practical and is not recommended.

FLAP INSET
When a temporalis flap is used for reconstruction that includes skin defects of the orbit or cheek, skin grafting is often performed after the muscle is secured to the bone. For functional muscle transfers or deeper reconstructions such as the skull base, no skin graft is required. For the reconstruction of defects, it is critical that the muscle be inset without tension and without kinking or torsion of the pedicle. For facial reanimation, it is critical that the muscle retain its proper resting length for good muscle excursion and postoperative function.
DONOR SITE CLOSURE
Harvest of the temporal muscle leaves a contour deformity in the temporal fossa. This is a cosmetic concern and should be addressed at the primary operation. Most commonly, remaining temporal muscle or temporal parietal fascia can be used to help fill this void.

![Diagram](image)

Only central section of muscle is used

Remaining muscle is released and centralized, filling void and maintaining contour

Fig. 5E-8

In some cases, implants are used at the initial procedure, depending on the surgeon’s preference. It is not uncommon that secondary surgeries, such as placement of an implant or fat grafting, are required to correct this deformity.
CLINICAL APPLICATIONS

This 36-year-old woman underwent resection of a left acoustic neuroma with complete loss of facial nerve function.

Fig. 5E-9  A, A gold loader was placed in the patient's left upper eyelid soon after tumor resection to protect the cornea. Six months after her neuroma resection, a static fascial sling was placed for the left lower eyelid. An early dynamic temporalis transfer was performed, creating a Mona Lisa type of zygomaticus-dominant smile. The anterior portion of the masseter was used to balance the strong dynamic upward pull of the temporalis muscle. B, Two years postoperatively, she demonstrates a balanced smile. No revision surgery was required. (Case courtesy Roger L. Simpson, MD.)

This 34-year-old woman presented with right-sided congenital near-complete paralysis.

Fig. 5E-10  A, The patient demonstrates her only function through a portion of the marginal mandibular nerve. She underwent placement of a gold loader and a static fascial sling for the right eyelids. B, A dynamic transfer of the temporalis muscle was performed to the right commissure and upper lip. At 9 months postoperatively, the patient shows excellent excursion of the upper lip and commissure, demonstrating complete relaxation. (Case courtesy Roger L. Simpson, MD.)
This young woman, as a 16-year-old girl, underwent resection of a hemangioma of her left cheek, which resulted in partial paralysis.

![Image](A)  
![Image](B)

**Fig. 5E-11**  
A. The paralysis affected her commissure and upper lip. At the time, a partial temporalis transfer was performed directly into the commissure and upper lip, creating an excellent, balanced smile.  
B. The photo on the right was taken approximately 10 years after the original reanimation procedure. (Case courtesy Roger L. Simpson, MD.)

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### Pearls and Pitfalls

- The temporalis muscle is valuable for the reconstruction of defects of the orbit and skull base, especially in elderly patients or those with significant medical comorbidities.
- The temporalis muscle can be harvested without interference with mastication.
- Harvest of the temporal muscle will leave a cosmetic deformity at the donor site that should be addressed.
- Fullness in the area of the zygomatic arch from passage of the muscle over the arch can be minimized by defatting the cheek in this area, or in some cases by removing the arch.
- When the arch is removed for transposition of the temporalis muscle, in most cases it should be replaced to avoid cosmetic deformities.
- When the temporalis is used for functional muscle transfer, the surgeon should consider a liquid or soft diet for the first 2 weeks to minimize mastication and allow healing of the muscle on inset and to prevent local complications.
EXPERT COMMENTARY
Roger L. Simpson

The versatility of the temporalis muscle in facial reconstruction is apparent in appreciating the various arcs of rotation of this muscle transfer. Soft tissue fill for deficiencies of the orbit and upper maxillary area are possible with the ease of rotation of the muscle and the reliability of its blood supply. Extension of the muscle to the lower maxillary and even mandibular cheek areas is possible by a partial resection of the zygomatic arch tracing the blood supply deep to the muscle and inferiorly.

Fig. 5E-12  Design of a standard temporalis transfer, with linear exposure of the muscle and rotation over the zygomatic arch into the commissure with its facial extension.

Recommendations
Planning
Use of the temporalis for contiguous muscle reanimation of unilateral or bilateral facial paralysis requires attention to design, tension, and muscle innervation. A reproducible facial reanimation using the temporalis muscle, in my experience, requires approximately two thirds of the width of the muscle harvested through a longitudinal incision in the hair-bearing scalp. Isolated areas of facial paralysis, such as just the levator labii superioris, can be reconstructed by a narrower slip of extended temporalis.

Fig. 5E-13  A partial left-sided paralysis limited to the zygomaticus major and minor and the levator labii superioris is an ideal clinical condition that lends itself to a partial temporalis muscle transfer. Pictured here is a partial temporalis transfer with its fascial extension to provide paralysis support for isolated loss of the levator superior.

Continued
Planning the dynamics of the transfer requires an appreciation of the type of smile present on the nonparalyzed side. Most individuals (67%) have a zygomaticus major–dominated smile; fewer (31%) show a combination of levator labii superioris and zygomaticus major and minor components. It is important to design the muscle transfer that will reproduce the form and balance of the patient’s smile.

**Technique**

The length of the muscle is variable. The transferred temporalis is turned over the zygomatic arch (as a fulcrum) for strong fiber excursion and pull. Fig. 5E–4 shows muscle or periosteal extensions of the transfer to the three key areas of attachment in smile restoration. However, I have not found that the muscle can be tapered in that fashion or that the periosteum provides a strong enough attachment to the muscle to reliably act in a functional gliding capacity.

Fig. 5E–5 shows an extension of the temporalis using fascia to insert into the orbicularis oris on the paralyze side. I extend the temporalis using its own deep temporal fascia.

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**Fig. 5E-14**  
A, Mona Lisa type of smile: A zygomaticus-dependent smile draws the commissures laterally and keeps the upper lip horizontally flat. B, Canine type of smile: A combination of the zygomaticus major and levator superior muscles to produce a gentle curvature.

**Fig. 5E-15** Preparation of fascia before isolating and contouring the temporalis muscle transfer.
Next, the tunnel is created from donor site to the upper lip and commissure.

**Fig. 5E-16** Cheek dissection creates a path for the transfer, designed to reproduce the smile pattern of the normal side. Care should be taken not to allow the transferred muscle to roll medial to the zygomatic prominence.

The fascial extension is carefully inset into the desired area of the commissure and lip.

**Fig. 5E-17** Tension is set with overcorrection. The temporalis fascial extension is attached to the upper lip and commissure.

With tension exerted on the muscle, insertion of the fascia is not into the atrophic orbicularis but into the stable vermilion of the upper lip and commissure, reproducing the pattern of the desired smile.

Setting the tension requires painstaking care. In a dynamic transfer, the muscle must produce a full, balanced excursion of the smile, as well as in relaxation, to produce just the right tension at rest. The force of the temporalis pull can be balanced by a portion of the masseter muscle transfer to hold the position of the commissure level during contraction.

**Fig. 5E-18** Overcorrection of the tension of the transferred temporalis muscle is essential in creating the correct balance of dynamic excursion. Approximately 28% of patients require a minor adjustment of the tension within 2 years.

*Continued*
Facial paralysis, whether partial or complete, will produce a degree of muscle atrophy on the affected side. The subcutaneous dissection of the tunnel in the cheek also defines the desired direction of pull of the muscle and the resulting shape of the smile. I use the broadest width of the temporalis that will fit into that tunnel without creating excessive bulk.

Fullness is present as the temporalis is turned over the zygomatic arch. The degree of fullness will vary with the thickness of the muscle, the tension created, and the degree of contraction of the muscle during function. Thinning the muscle is not suggested as decreased contractility or nerve injury to the transfer is possible.

With the use of a wider muscle flap, I have found that the primary closure of the remaining temporalis muscle donor area is not possible. Rotation and tension on the remaining segments, as shown in Fig. 5E–8, will cause additional volume depletion of the temporal fossa. This will further accentuate the fullness of the muscle turnover.

The use of a temporal implant, or better yet, acellular dermal matrix, will create an excellent form at the temple region. A carved solid or porous polyethylene implant is one solution in the wide temporalis donor area to treat the temporal hollowing seen after transfer. These implants have been associated with capsule formation, pain, pressure, and contour changes. Currently I prefer a rolled sheet of acellular dermal matrix to fill the temporalis donor site, which gives ample fullness and contour. The soft consistency has reduced postsurgical complications of capsule formation, extrusion, and contact pain.

The use of thin segments of the temporalis muscle for dynamic reconstruction of the eyelids has been less than satisfactory in my hands. The transfer of narrow slips of muscle and/or fascial extensions in proximity to the lash line have produced (when remaining dynamic) a lateral pull to the eyelids, creating a sphincter like closure. The degree of relaxation has not been completely predictable often leaving a partial closure of the upper lid. I prefer the combination of a gold loader placed over the tarsal plate of the upper eyelid to initiate descent, and a well-designed static sling for the lower eyelid.

The temporalis muscle may also be transferred to the commissure and upper lip as a lengthening myoplasty, as described by Labbé. The fascial portion attached to the coronoid process is advanced into the cheek after mobilization of the muscle in the temporal fossa. Tension of the muscle after transfer has a critically important role, as in the turnover procedure. Loss of contour of the temporal fossa is avoided, because the muscle and its relationship to the zygomatic arch remain intact.

**Take-Away Messages**

The use of the temporalis muscle for either static or dynamic reconstruction of the face and orbital area achieves consistently good results. Its rich blood supply and well-positioned pedicle makes it ideal for large areas of soft tissue coverage. Temporalis innervation and options for its direction of pull make the muscle well suited for facial paralysis reanimation.
Bibliography With Key Annotations


This retrospective review reported on the use of the temporalis muscle flap for reconstruction of different types of intraoral defects in eight patients. All patients previously wore obturators as a nonsurgical treatment of their defects. Criteria used to evaluate the results of this technique included flap necrosis, facial nerve deficit, limitation of mandibular range of motion, and cosmetic deformity from scarring of the incision line or from loss of muscle volume in the temporal fossa. The patients were also evaluated for their degree of satisfaction with their speech and mastication with the obturator preoperatively and with the flap postoperatively. Also reviewed were the success rates and complications with use of the temporalis muscle flap reported in the English-language literature during the past 14 years. All eight patients in this series had their defects successfully reconstructed, which eliminated any further need for prosthetic obturation of the defect. No flap necrosis occurred, and there were no facial nerve deficits or long-term changes in mandibular range of motion. Slight temporal hollowing was seen in the first three patients.


The authors presented their experience with the use of the simple, reliable, and predictable temporalis myofascial flap (TMF) in rehabilitation and reconstructive surgery in older cancer patients whose health was compromised in a way that precluded the use of microvascular free flaps. The series included 10 patients (8 men and 2 women) ranging in age from 62 to 85 years. A full-thickness anteroinferiorly based TMF was used in five patients for palatal reconstruction, three patients for buccal lining reconstruction, and two patients for reconstruction after resection of facial skin and buccal mucosa. The TMF survival rate in this study was excellent, with an 80% success rate (2 minor complications). Complications included one case of a partial distally necrotic flap that resolved after local debridement and did not require further flap manipulation and one case of transient, spontaneously resolved facial nerve (temporal branch) palsy and limited mouth opening (less than 20 mm), which also resolved after judicious physiotherapy. The TMF was found to have a fairly low complication rate, was relatively easy to use, and had a predictable outcome.


The temporalis muscle flap for reconstruction of the maxilla is a commonly used technique at the moment. One of the disadvantages of applying this technique is the scar generated by the anesthetic in the temporalis fossa and the depression of this area. The authors presented a new method for endoscopic harvesting of the muscle flap through minimal incisions situated in the temporalis fossa and preauricular region. This endoscopic technique has not been described in the literature for a hemimaxillary reconstruction. These authors described the first case of a maxillary reconstruction with an endoscopically assisted temporalis muscle flap with excellent results.


The authors presented a modified technique for temporalis transfer: instead of the traditional stripping of the temporalis from its origin, its attachment at the coronoid is removed, and to its end, the harvested fascia lata graft was sutured to lengthen the muscle’s action. These fibers were then passed to the orbicularis oculi and oris to aid in reanimation and improve their tone. The procedure is less extensive, provides a direct line of pull with good functional results, and no muscle atrophy, since vascularity and innervation are maintained. No complaints of paresthesia, hypoesthesia, or scarring on the donor leg were noted. None of the patients required revision surgery for unacceptable contour or asymmetry. This simple procedure has aided in the reconstruction of a natural, symmetrical smile with highly successful results.

Dynamic muscle transfers offer the hope of improved facial support and symmetry, with volitional movement. These are most commonly employed for reanimation of the oral commissure to produce a smile. In addition, muscle transfers have been used successfully to reestablish eye closure. Long-standing facial paralysis presents challenges quite distinct from paralysis that is managed early after onset. In this situation, most commonly, dynamic muscle transfers are used. The alternative is free tissue transfer. The advantages and disadvantages of each of these two options were discussed.


The fascia temporalis is a thin and well-vascularized tissue, and it is versatile for use in reconstructive surgery. It can be used as an island flap in defects of the head and neck or as a free flap in reconstructions of different anatomic regions. As a “living” spacer for treating wrist ankylosis, its use has not yet been described. The authors discussed transfer of the free fascia temporalis into the wrist for wrist ankylosis in patients affected by severe rheumatoid arthritis. Four flap transfers were performed in three patients. Preoperative flexion/extension in the wrist was absent or almost absent and painful, resulting in severely impaired daily activities. After resection of the distal ulna and radius and the proximal surfaces of the proximal row of the carpal bones, the free fascia was used to replace the wrist joint. Postoperative wrist flexion/extension was 45 to 50 degrees. In all patients, this procedure allowed painless movement of the wrist and improved ability to perform daily activities. A 2-year follow-up showed no recurrence of wrist problems, and the articular space was maintained. The use of the free fascia temporalis offers a good alternative to arthrodesis, maintaining sufficient function for daily activities.


Facial palsy is an unpleasant disorder that inhibits vital movements and facial expression. There are many surgical techniques that use the neighboring nerve fibers to reanimate the face, such as end-to-end or side-to-end anastomosis with hypoglossal, glossopharyngeal, accessory, or mandibular nerves. The donor fiber can be derived from the homolateral or heterolateral side. The reconstruction can be completed by cosmetic surgery using parietal muscle or free muscular flaps. The authors presented the modified May technique described by Darrouzet with rerouting of the facial nerve in the mastoid portion of the temporal bone. This procedure elongates the facial nerve stump with simultaneous rerouting of the facial nerve. Three temporal bone blocks with adjacent tissues were taken from cadavers. The length of the isolated nerve stump was measured and photographed. The length of the prolonged nerve stump was 13 mm in each case. After adding to this the length of the trunk (the portion between the stylomastoid foramen and pes anserinus), the fragments of rerouted nerve measured up to 21 mm. This distance allowed facial-hypoglossal anastomosis using only one neurorrhaphy without increased tension.


The authors presented a preliminary anatomic analysis that could lead to a new technique for treating facial nerve paralysis. The masseteric nerve leaves the infratemporal fossa through the mandibular notch, accompanied by the masseteric artery. At this level the nerve consisted (in 9 of 36 cases they studied) of only one branch (25%), in 17 cases of two branches (47%), in nine cases of three (25%), and in the remaining case of four branches (2.8%). There are three main reasons for considering the masseteric nerve as a possible donor for at least the orbicular branch of the facial nerve: (1) The approach to the mandibular notch is quite simple; (2) since the nerve consists of two or more branches in 75.0% of the cases, severe dysfunction of the masseter muscle should not occur; (3) if there is complete denervation of the masseter muscle, its function may be taken over by the temporalis muscle.


The authors presented a retrospective chart review of 16 patients who underwent a combined approach for resection of palatal carcinoma; 5 of the 16 were edentulous. Six types of tumors were treated: adenoid cystic carcinoma (3 patients), low-grade mucoepidermoid carcinoma (5 patients), squamous...
cell carcinoma (3 patients), polymorphous low-grade adenocarcinoma (2 patients), osteosarcoma (1 patient), ameloblastoma (1 patient), and hyalinizing clear cell carcinoma (1 patient). Main outcome measures were the postoperative diet, velum competence, flap viability, complications, and survival. Fifteen (94%) of 16 patients were able to resume their preoperative diets. No velopharyngeal insufficiency was encountered. All flaps survived and none required repeated surgical intervention. Five patients developed serous otitis media, and two patients required flap revision secondary to posterior choanal obstruction. One patient died of complications unrelated to the procedure.


In this study, 60 human cadavers were investigated to identify the arteries and nerves supplying the temporalis muscle. In all specimens, three arteries supplying the temporalis were identified: the anterior deep temporal artery (anterior part, 30% muscle mass), the posterior deep temporal artery (central part, 51% muscle mass), and the medial temporal artery (occipital and in 25% upper part, 19% muscle mass). Motor branches of the trigeminal nerve innervated the temporalis: the deep temporal nerves of the mandibular nerve (98%, central part), branches of the buccal nerve (95%, anterior part), and branches of the masseteric nerve (69%, posterior part). They noted remarkable variation in the innervating nerve branches, and in 12% peripheral anastomoses between the motor nerve branches. The various numbers of innervating nerve branches demonstrate the difficulty of creating innervated or selectively denervated pedicled muscle flaps for reinnervation. Nevertheless, at least two different pedicled flaps using the anterior or central part of the temporalis can be selectively used for reconstructive surgery.


This paper was a retrospective review of seven consecutive patients who underwent orthodontic transfer of the temporalis muscle insertion for the treatment of long-standing facial paralysis. The patients underwent facial retraining physical therapy before and shortly after the procedure. Outcomes measured included patient satisfaction, objective measurements of oral commissure elevation with smiling, and physician grading of preoperative and postoperative patient photographs. Patient satisfaction was high, with a mean score of 8.5 (possible score of 10). Four patients were physician graded as excellent to superb. The other three patients were rated as having good postoperative results. Movement was identified in every patient and ranged from 1.6 to 8.5 mm, with mean movement of the oral commissure of 4.2 mm. One patient developed a postoperative salivary fluid collection that required drainage.


Approaches to the infratemporal fossa and nasopharynx are difficult because of the anatomic complexity of these regions. The authors described their experience with osteoplastic maxillotomy with their own modifications and evaluated oncologic outcomes and postoperative quality of life. Ten patients underwent osteoplastic maxillotomy; three had a diagnosis of malignancy, and seven had nasopharyngeal angiofibromas (NPAs). A Weber-Ferguson incision was made to develop facial flaps and preserve the vascularity of the maxilla. Osteotomies were performed through the facial aspects of the maxilla, on the orbital rims, and on the malar eminence for the medial variant of the procedure. The anterolateral variant involved descent of the temporalis muscle, with preservation of the facial nerve, and a zygomatic osteotomy. Four craniotomies were done. Two patients had the medial variant of the procedure, and eight had the anterolateral variant. The complications were transient and mild. The patients with malignancies are alive with no disease; there was one recurrence among the seven patients with NPAs. Aesthetic results were excellent in eight patients, and there was no change in basic functions in eight patients.


Temporomandibular joint ankylosis (TMJ) is a pathologic process caused by damage of the mandibular condyle. When this occurs during the developmental age, it results in an alteration of the entire
maxillofacial complex. Therefore surgical methods to remove the temporomandibular ankylosis also require procedures to correct the secondary maxillofacial deformity. Distraction osteogenesis induced the authors’ center to modify the surgical protocol for the treatment of patients who develop TMJ ankylosis and secondary maxillomandibular deformity. They treated four patients with monolateral ankylosis of the TMJ and serious deformities of the maxillomandibular complex caused by functional limitations. During the same operation, arthroplasty was performed, with removal of the ankylotic block and the interposition of a temporal muscle flap in the new articular space; an intraoral osteodistractor was also positioned to lengthen the mandible. All patients recovered the eurhythmy of the face and good symmetry was reestablished. At an average 12-month follow-up, the average opening of the mouth was at least 35 mm.


Oral submucous fibrosis is a collagen disorder that affects the submucosal layer of the upper digestive tract. The major cause is the habit of betel quid chewing, which is common in central, southern, and Southeast Asia. The progressive and irreversible course of the disease results in trismus, dysphagia, xerostomia, and rhinolalia. The most serious complication of this disorder is the development of oral carcinoma; the incidence in different series varies from 1.9% to 10%. A sufficient mouth opening can be achieved by complete release of fibrotic tissue, and coronoidectomy and temporal muscle myotomy is performed when needed. Reconstruction of the resultant defect can be best achieved by microsurgical free tissue transfer because of the discouraging results with skin grafting or local flaps. The authors reported a series of 26 patients who underwent reconstructive surgery with small radial forearm flaps after release of submucous fibrosis with or without temporalis muscle myotomy and coronoidectomy. All patients were men, with a mean age of 40.1 years (range 18 to 62 years) and all had a history of betel nut chewing ranging from 8 to 40 years. Three patients developed squamous cell carcinoma of the oral cavity 24 to 36 months after submucous fibrosis release. Two of them occurred in the release site and the other one occurred at the soft palate. Oral cancer occurred in three of 13 patients who had received release of submucous fibrosis and who were followed for longer than 2 years (range 24 to 48 months), which means that 23% of these patients developed squamous cell carcinoma of the intraoral mucosa. The high risk of cancer occurrence strongly indicates the importance of an earlier and more aggressive surgical approach toward submucous fibrosis, and regular long-term follow-up.


The authors reviewed 77 cranial base reconstructions performed by the Department of Plastic Surgery at the University of Texas M. D. Anderson Cancer Center between 1993 and 1999. They analyzed the impact of the location of the defect, type of reconstruction, type of dural repair, and history of preoperative radiation and chemotherapy on the rate of complications and patient survival. They found that neither the type of reconstruction nor the location of defect showed a significant effect on patient survival. In this experience, local flaps such as pericranial or temporalis muscle flaps were found to be good choices for reconstruction of smaller anterior or lateral cranial base defects. For defects that required larger amounts of soft tissue, free flaps were appropriate. With proper patient selection, successful cranial base reconstruction can be performed with either local or free flaps with a low incidence of complications.


The author performed facial reanimation by using functioning free muscle transplantation in 116 cases from 1986 to 2000. Three consecutive 5-year periods were presented in relation to each stage of the author’s technical improvement. In the first 5 years he encountered bulkiness and asymmetrical smiling with weak gum exposure that required correction. During the second 5 years there were technical
improvements, but with residual deformities. The third 5-year period was one of technique refinement. The author extended the utility of the gracilis for different and more challenging problems, such as the use of a muscle plus skin two-unit composite flap connected by the septoperforator nutrient vessels, not only for facial reanimation but also for intraoral contracture release or extraoral facial soft tissue and skin deficits replacement.


The authors described the indications and advantages of the temporalis myofascial flap in the reconstruction of surgical defects after partial maxillectomies. This flap is thin and reliable and can be used as an alternative to free flap tissue transfer in the reconstruction of partial defects of the upper maxilla. The surgical steps to raise the flap are simple, but during the dissection the surgeon must be careful to avoid damage to the frontotemporal branches of the facial nerve on the outer surface and to the feeding vessels on the inner surface of the temporal muscle. In this series, no major surgical complications were observed, and no injuries to the facial nerve branches were reported. Neither total nor partial flap losses occurred. Postoperative aesthetic and functional results were satisfying.


The continued use of the temporalis muscle flap in maxillofacial surgery for more than a century serves as a testament to its versatility and reliability. The technical ease of its procurement and the amount and quality of tissue available make this flap a valuable tool in the armamentarium of the reconstructive surgeon.


The authors reported on 41 consecutive patients who received primary temporalis myofascial flap reconstructions after cranial base tumor resections in a 4-year period. Patients included 37 males and 4 females ranging in age from 10 to 65 years. Two patients received preoperative and 18 postoperative radiation therapy. Follow-up ranged from 4 to 39 months. The whole temporalis muscle was used in 26 patients (63.4%) and only part of a coronally split muscle was used in 15 patients (36.6%). Nine patients had primary donor site reconstruction using a Medpor temporal fossa implant; these had excellent aesthetic results. There were no cases of complete flap loss. Partial flap dehiscence was seen in six patients (14.6%); only two required surgical debridement. None of the patients developed cerebrospinal leaks or meningitis. One patient was left with complete paralysis of the temporal branch of the facial nerve. Three patients (all had received postoperative irradiation) developed permanent trismus. The temporalis myofascial flap was found to be an excellent reconstructive alternative for a wide variety of skull base defects following tumor ablation. It is a very reliable, versatile flap that is usually available in the operative field, with relatively low donor site aesthetic and functional morbidity.


From the authors’ three-dimensional video analyses they learned that the advantages of a one-stage procedure are far outweighed by the disadvantages. A three-stage concept to a one-stage procedure was preferred because of the safety of having a cross-face nerve graft to cover the distance from the healthy facial nerve to the nerve of the muscle transplant without problems and without the danger of tension on the nerve suture line because of shortage of the muscle nerve. In addition, this concept provides independence from anatomic variations, such a very proximal muscle hilus in the latissimus dorsi muscle, which results in too short a muscle nerve. Only face-lift incisions are necessary, without the need of an additional incision in the nasolabial fold while using a cross-face nerve graft. This technique allows freedom to position the muscle graft on the paralyzed side, with free choice of the position of the transplant hilus. The superficial temporal vessels can be used for microvascular anastomoses. The three-stage concept prevents a scar in the submandibular region, with its tendency of hypertrophy, especially if it is connected to the preauricular incision. Different functional territories of one muscle transplant for eye closure and for smile are only possible in combination with two cross-face nerve grafts.

Intraoperative electrical stimulation of the temporalis muscle, employing direct percutaneous electrode needles or transcutaneous electrical stimulation electrodes, was used in 11 primary and four secondary cases with complete facial palsy. The duration of the facial paralysis was up to 12 years. Postoperative follow-up ranged from 3 to 12 months. The insertion points of the temporalis muscle tendon to the nasolabial fold, upper lip, and oral commissure had been changed according to the intraoperative muscle stimulation in six patients of the 11 primary cases (55%) and in all four secondary (revisional) cases. A coordinated, spontaneous, and symmetrical smile was achieved in all patients by 3 months after surgery by employing speech therapy and biofeedback.


The authors developed a simple, easy modification of the orbitozygomatic approach using a one-piece pedunculated craniotomy. This modification prevents atrophy of the temporal muscle, resulting in temporal fossa depression and atrophy of the free bone graft resulting in the occurrence of bone pits along the line of the craniotomy. The scalp flap is elevated in the plane between the superficial and deep layers of the temporal fascia. The temporal muscle is dissected from the temporal plane by subperiosteal elevation with intact insertion to the superior temporal line of the temporal muscle, which results in the creation of a subperiosteal tunnel beneath the temporal muscle. The one-piece frontoorbitozygomatic bone flap is hinged on the temporal muscle.


The temporal flap is of great interest in head and neck reconstruction when a skin graft or a local flap cannot be used. It has shown important results in facial reanimation and in oncologic surgery. The authors described their experience with the pedicled flap in reconstruction of middle third face defects in eight oncologic patients. This flap allows coverage of bone and noble structures such as the periorbital, auricular, frontal, or parotid gland areas. Few major or minor complications were seen, and good aesthetic results were achieved. This can be done with or without adjuvant radiation therapy. However, the patient prognosis depends on the stage of the tumor.


The authors reported a case of immediate facial reanimation resulting from functional latissimus dorsi myocutaneous flap transfer and funicular grafting of the thoracodorsal nerve after cheek tumor ablation. After wide excision of the tumor, including the facial nerve except the temporal branch and part of the zygomatic major muscle and masseter muscle, the authors reconstructed the cheek skin and provided movement by performing a small-segment latissimus dorsi myocutaneous flap transfer using Harii’s method and the defect of the buccal and marginal mandibular branches of the facial nerve by funicular grafting from one of the two funicles of the thoracodorsal nerve. After 6 months, the transplanted, small-segment latissimus dorsi muscle showed good voluntary movement, and the lower orbicularis oris and depressor oris presented good functional recovery.


The author reported a retrospective histopathologic analysis to demonstrate the histopathologic fate of tissues used for mastoid obliteration over 30 years by archival temporal bone microscopic sections. From the laboratory’s database, 17 temporal bones from subjects who had undergone mastoid obliteration procedures were identified. The microscopic appearance of the obliteration tissue was described, and
microphotographs made of significant findings. Fat and bone chips, or paté, retained their bulk in the obliterated space, whereas subcutaneous tissue and muscle lost bulk but seemed to promote healing. Some substances, such as bone wax, used for hemostasis and buried under obliteration tissue, were found to produce a subclinical inflammatory reaction, but other materials, such as Surgicel and Gelfoam, did not.


The author reported on 11 patients (10 men and 1 woman, average age 61.3 years) who underwent free flap reconstruction of tumor-related defects of the scalp, forehead, and temporal region. Flaps were selected to achieve acceptable functional and aesthetic results combined with negligible donor site morbidity. Eight patients presented with tumor recurrences after previous surgery, irradiation, and/or chemotherapy. The average extension of defects was 169.5 (range 30 to 600) cm². Free flaps employed for reconstruction included anterolateral thigh flaps, a suprafascial radial forearm flap, a lateral arm flap, a latissimus dorsi muscle flap, and a myocutaneous vertical rectus abdominis flap. The anterolateral thigh perforator flap offers excellent coverage of tumor-related defects of the scalp that require a thin flap for adequate contouring. The customized harvested myocutaneous anterolateral thigh flap is regarded as an elegant option for covering defects that consist of both deep and superficial areas. Fascia lata and nerve grafts are available at the same donor site. This easily allows additional procedures for cosmetic and functional improvement that are highly beneficial to patients.


In this series, the authors used the temporalis myofascial flap for the reconstruction of different types of maxillofacial defects and as an interposing material in temporomandibular joint surgeries. They found this flap to be very valuable in maxillofacial reconstruction.


The authors presented a study of 27 patients with bilateral or unilateral facial paralysis, aged 16 to 61 years, who received 45 muscle transfers. They assessed the ability of the masseter motor nerve–innervated microvascular muscle transfer to produce an effective smile in adult patients. The operation consisted of a one-stage microvascular transfer of a portion of the gracilis muscle that is innervated with the masseter motor nerve. All 45 muscle transfers developed movement. Age did not affect the amount of movement. Patients older than 50 years had the same amount of movement as patients younger than 26 years (p = 0.605). Ninety-six percent of patients reported satisfaction with their smile.


A case of true bilateral ankylosis of the temporomandibular joint (TMJ) was presented. A 19-year-old male patient had a life-threatening ear infection at the age of 10, resulting in a progressive restriction of his mouth opening. He presented with almost complete lack of mobility of the mandible. Surgical treatment included a resection of the ankylotic mass, interpositional temporalis composite muscle flaps, early mobilization, and aggressive physiotherapy. The functional results of the interpositional arthroplasty were excellent. After a 2-year follow-up, an augmentation genioplasty was performed to improve facial aesthetics.


The authors used the reverse temporalis muscle flap for orbital reconstruction after exenteration in six patients, with successful results. This flap enables placement of highly vascularized tissue that provides the reconstructive goals of primary healing, obliterates dead space with separation of the orbit from the nasal cavity or sinuses, provides the potential for early postoperative radiotherapy, and offers possible flaps that can be used in combination for complex, wide defects.

Orbital exenteration is a disfiguring operation that involves the total removal of the orbital contents, with partial or total excision of the eyelids. Common methods of orbit reconstruction include pectoralis myocutaneous pedicled flap and free tissue transfer. The purpose of this study was to illustrate that the entire temporalis muscle may be used by creating a large window in the lateral orbit, without resection of the lateral orbital rim. Orbital exenteration was performed on four cadavers. A window was created in the lateral orbit using a 4 mm pineapple burr. Three parameters were measured: the distance between the zygomatic arch to the superior aspect of the temporalis muscle, the width of the temporalis muscle, and the length and width of the lateral orbit window. The free edge of the transposed temporal muscle was then sutured to the skin edge around the bony orbit. This procedure was then performed on a 73-year-old man who had undergone right orbital exenteration for ocular melanoma and then postoperative radiation. The patient recovered well without complications, with a well-healed skin graft over the top of the muscle flap. An adequate bony window can be made to allow transfer of the entire temporalis muscle for orbital reconstruction without resecting the lateral orbital rim or entering the middle cranial fossa.


The authors described the temporalis muscle flap (TMF) surgical technique, with attention to specific methods for preventing facial nerve injury and donor site deformity. They presented a patient with a malignant tumor in the upper jaw, palate, and inferior half of the nasal cavity who underwent extensive surgical excision and the resultant defect was successfully reconstructed with a TMF. During a 5-year follow-up there were no complications associated with the flap or the temporal implant used for donor site reconstruction, and no local recurrence or tumor metastasis.


The authors described a novel fascial flap of the temporal region and its use for reconstruction in otologic and neurotologic surgery. This flap was used in 15 consecutive patients to solve a wide variety of reconstructive problems after otologic procedures. No additional morbidity was observed from the use of this flap. There were no complications related to the reconstruction. Adequate exposure for raising this flap was obtained using standard incisions for the otologic procedures. Follow-up ranged from 2 to 25 months. This fascial flap provides a wide surface area of tissue on a narrow-based pedicle capable of a wide arc of rotation. It provides thin, pliable tissue that can be adapted to the needs of various reconstructive otologic/neurotologic problems.


Lateral approaches have traditionally been used to gain access to lesions of the infratemporal fossa (ITF). However, dysfunction of the facial nerve secondary to its translocation, conductive hearing loss, and dental malocclusion because of mandibular head resection or dislocation are significant limitations associated with some of these approaches. Although facial nerve translocation and extended maxillotomy approaches avoid some of these drawbacks, they are invasive and require extensive osteotomies and facial incisions. To avoid these potential complications and maintain an extranasal/extraoral exposure, the authors studied the use of a lateral and posterior extension of an anterior transtemporal approach to the cavernous sinus on 12 cadaver specimens and two dry skulls. An initial nasolabial fold incision, followed by an en bloc osteotomy of the anterior and lateral maxilla provides a window into the medial ITF. After osteotomy of the pterygoid plate and the posterior maxillary wall, the
floor of the middle fossa is exposed to reveal the mandibular and maxillary divisions of the trigeminal nerve exiting their respective foramina. The floor of the middle fossa is then drilled posterosuperior to the foramen ovale to gain access to the course of the C3-C4 portion of the petrous carotid artery and the Eustachian tube. The upper two thirds of the clivus and the pituitary gland are accessed after drilling of the floor of the sella turcica and form the posterior limit of this exposure. The technique offers a trajectory to the medial ITF and skull base that does not necessitate palatal splitting or opening of the nasopharynx. The anterior route avoids TMJ disruption, and spares the lacrimal apparatus and all branches of the facial nerve. In addition, the reflected pterygoid muscle can be used as a vascularized flap for closure of the skull base defect.


The temporalis muscle flap (TMF) is a valuable reconstructive technique that is used for a variety of challenging defects. However, its use for repair of skull base defects is less common. A retrospective chart review was conducted for 35 patients who underwent reconstruction of skull base defects between 1999 and 2006 at a tertiary referral hospital. Patients with skull base defects after trauma or extirpative surgery underwent reconstruction with a TMF. The measured outcomes were as follows: defect size/location, need for additional flaps, bone necrosis, hardware exposure, delisence, CSF leak, and meningeitis. Forty-two patients underwent reconstruction with a TMF, and 35 of 42 patient records were available for review. No flap failures, one transient CSF leak, three hardware exposures distant from the temporalis recipient site, and three hydroxyapatite cement infections or foreign body reactions were observed.


The authors performed a retrospective chart review of a consecutive series of 24 patients who underwent a total of 26 temporalis flaps (two bilateral) for reconstruction of defects of the oropharynx, nasopharynx, and base of tongue. Variables and outcomes that were examined included defect location, size, adjunctive therapy, complications, and ability to tolerate oral intake at follow-up. There was no evidence of flap failure in the series. There were two cases of minor flap loss related to early prosthetic rehabilitation, and two cases of transient frontal nerve paralysis were noted. A 30.8% rate of complication (all minor) was noted in this study. At a mean follow-up of 12 months, 54.2% of patients were tolerating a full diet, 37.5% were tolerating most of their nutrition by mouth, and 8.3% were G-tube dependent.


Good harmony of color and texture with surrounding tissues, thinness and adequate pliability, good alignment, obliteration of the cavities, and minimal donor site morbidity are the main features of an ideal flap to be used in the reconstruction of craniofacial defects. Despite the numerous local, regional, and free flaps that have been described, to date, there has not yet been an ideal flap. The authors discussed the reconstruction alternatives presented by the temporal site and its outcomes. The temporal region is a good donor site for closure of craniofacial defects, by means of its rich vascular network and almost all types of tissue, including skin, fascia, muscle, galea, calvarial bone, and periosteum. The attractiveness of this region for reconstruction has gradually increased as clinical experiences have advanced and its anatomy has been better understood.


Fifteen consecutive cases of CSF fistulas treated at the authors’ institution were retrospectively reviewed. All patients presented with otorrhea. Eleven patients had previously undergone ear surgery. A middle fossa approach was used in all cases. The authors used a thin but watertight and vascularly preserved temporalis muscle flap that had been dissected from the medial side of the temporalis muscle and that was laid intracranially on the floor of the middle fossa, between the repaired dura mater and petrous bone. The median follow-up period was 2.5 years. None of the patients had recurrence of otorrhea or meningitis. There was no complication related to the intracranial temporalis muscle flap (e.g., seizures...
or increased intracranial pressure caused by muscle swelling). One patient developed hydrocephalus, which resolved after placement of a ventriculoperitoneal shunt 2 months later. The thin, vascularized muscle flap created an excellent barrier against the recurrence of CSF fistulas and avoided the risk of increased intracranial pressure caused by muscle swelling. This technique is particularly useful in refractory cases.


Eye reanimation techniques and specifically blink restoration reinstates the cornea’s protective mechanism and recovers a more natural appearance and eye function. Both dynamic and static procedures have been used to augment eye closure, but only dynamic procedures can lead to blink restoration. In this study, the experience of a single surgeon was presented in a retrospective review of 95 adult patients who underwent dynamic procedures for blink restoration. The patients were divided into two groups. Group A (n = 75) included patients who underwent nerve transfers, including cross-facial nerve grafting and subsequent microcoaptations, mini-hypoglossal nerve transfers, and direct orbicularis oculi muscle neurotization. Group B (n = 20) included patients who underwent eye sphincter substitution procedures, including pedicled frontalis or mini-temporalis transfers, free platysma, occipitalis, gracilis subunits, extensor digitorum brevis, and a slip of adductor longus transfer. Objective blink ratios were measured. Denervation time ranged from 7 months to 42.12 years; the mean denervation time was 13.02 years. Blink improvement was noted in all patients. Blink scores and ratios were consistently better in group A than in group B.


In this study, cases of fair or moderate outcomes from a free muscle transfer received a segmental temporalis transposition to upgrade the functional and aesthetic results. From 1981 to 2007, 153 patients received a free muscle transfer for smile restoration. Of all patients, 72% (n = 110 patients) required a third stage of revisions. In 41 cases, a mini-temporalis transfer was used to augment moderate outcomes of a free muscle transfer. The exclusion criterion was less than 3 months’ follow-up; thus six patients were not evaluated. Each patient was videotaped at three successive points (preoperatively, following free muscle transfer, and following mini-temporalis transfer). Five independent observers graded patients’ videos using a five-category scale from poor to excellent. The averaged scores were higher after free muscle transfer in comparison with the preoperative scores (Wilcoxon signed-rank test; p < 0.0001). After mini-temporalis transfer, 97.1% of the patients had scores that were increased further and 2.8% had the same scores. Alopecia along the coronal incision was seen in four patients, and hollowing of the infratemporal fossa was seen in five.


The authors studied the events involved in neovascularization using a well-characterized model of angiogenesis in rabbits by which neovascularization is induced by transfer of a well-perfused rectus abdominis muscle flap to an ischemic limb. Using this model, the authors demonstrated that basic fibroblast growth factor (bFGF) expression is induced in normal myofibers, and bFGF is released in the wound fluid at the ischemic/nonischemic interface. The highest concentrations of bFGF were detected on days 14 and 21 after surgery. They also showed that the number of mast cells and their degranulation correlate with the release of bFGF from adjacent muscle tissue and the appearance of the growth factor in the wound fluid. There appears to be a temporal correlation between number of mast cells, their degranulation, and the release of bFGF during angiogenesis in vivo.


Large temple and suprabrow lesions can pose a reconstructive challenge. When the lesion extends anterior to the hairline, aesthetically acceptable local flaps may be difficult to design. The authors described a modified scalp flap (part Converse scalping flap and part scalp rotation flap) that can be tailored to reconstruct a variety of difficult temple and suprabrow lesions while simultaneously maintaining eyebrow...
position. The modified scalp flap is raised in a subgaleal plane until approximately 2.5 cm above the brow. The modified scalp flap was used to reconstruct temple and suprabrow lesions in 10 patients ranging in age from 4 months to 22 years, with no complications. Four typical cases were presented.


The use of endoscopy in the transblepharoplasty midface lift is essential for preventing the complications of facial nerve injury and bleeding. Complete observation allows precise dissection and release of all structures in the composite flap. This technique fully preserves the zygomorphic nerve plexus and prevents denervation of the orbicularis oculi and zygomatic muscles. Blind dissection has a significant probability of denervation of the entire zygomaticus muscle complex, and avulsion of the zygomaticofacial vessels, with associated postoperative bleeding complications. The modification involving suturing of the “vest” of the combined lateral orbital periosteal and superficial layers of the deep temporal fascia over the elevated “pants” of the orbicularis periosteal flap provides very secure fixation for suspension of the lower eyelid and midface. The use of slowly absorbable polydioxanone sutures for this technique prevents the problems caused by permanent sutures beneath the very thin skin of the lateral canthal area. Careful trimming of the prominent roll of the orbicularis muscle that often develops with suspension eliminates the uneven contour and yields a smooth lower lid appearance.


The authors compared the short-term clinical consequences between these two interpositional materials in 20 patients with operated TMJ ankylosis. The presurgical maximum incisional opening and lateral excursion were not significantly different between the two groups. Three months after the operation, patient evaluation did not reveal a significant difference, considering the amount of maximum incisional opening, lateral excursion, and mandibular deviation.


Before performing plastic and aesthetic surgery around the buccal area, the authors reviewed the anatomic structures of the buccal fat pad in 11 head specimens (22 sides of the face). The enveloping fixed tissues and the source of the nutritional vessels to the buccal fat pad and its relationship with surrounding structures were observed in detail, with the dissection procedure described step by step. Based on the findings of the dissections, the authors provided several clinical applications for the buccal fat pad, such as the mechanism of deepening the nasolabial fold and possible rhytidectomy to suspend the anterior lobe upward and backward. They suggested that relaxation, poor development of the ligaments, or rupture of the buccal fat pad capsules can make the buccal extension drop or prolapse to the mouth or subcutaneous layer.
# ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>Masseter muscle extends from the zygoma to the ramus, angle, and body of the mandible.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>$8 \times 8$ cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>Zygomatic arch. Superficial belly originates from the anterior and middle arch; posterior belly arises from the deep surface of the zygomatic arch.</td>
</tr>
<tr>
<td>Insertion</td>
<td>Combined muscle bellies insert on the lateral surface of the ramus of the mandible; includes the lower portion of the coronoid process.</td>
</tr>
<tr>
<td>Function</td>
<td>Muscle of mastication; it elevates the mandible to close the mouth and to assist in chewing.</td>
</tr>
<tr>
<td>Composition</td>
<td>Muscle.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type I.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Masseteric artery.</td>
</tr>
<tr>
<td>Minor Pedicle</td>
<td>Facial artery.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td><em>Motor</em>: Masseteric nerve, branch of the mandibular division of the trigeminal nerve.</td>
</tr>
</tbody>
</table>
Section 5F

HEAD AND NECK

Masseter Flap

CLINICAL APPLICATIONS

Regional Use
Head and neck

Specialized Use
Facial reanimation
ANATOMY OF THE MASSETER FLAP

A

Fig. 5F-1

Dominant pedicle: Masseteric artery
ANATOMY

Landmarks  The masseter muscle runs from the zygomatic arch to the ramus of the mandible. It is largely covered by the parotid gland posteriorly and by facial muscles anteriorly. Deep to the facial musculature but superficial to the masseter, the parotid duct runs transversely. The facial artery and vein also run above and superficial to the muscle, as do the branches of the facial nerve.

Composition  Muscle.

Size  8 × 8 cm.

Origin  The muscle has deep, middle, and superficial bellies. The superficial belly is largest and originates from the anterior two thirds of the zygomatic arch. The deeper bellies are smaller and originate from the posterior portion of the zygomatic arch.

Insertion  Combined muscle bellies insert on the lateral surface of the ramus of the mandible; this includes the lower part of the coronoid process.

Function  One of the four muscles of mastication. Because of this redundancy, it can be used without functional deficit.

Arterial Anatomy (Type I)

Dominant Pedicle  Masseteric artery
REGIONAL SOURCE  Internal maxillary artery.
LENGTH  3 cm.
DIAMETER  1.5 mm.
LOCATION  Vascular pedicle enters the muscle posteriorly midway between the zygomatic arch and the mandibular body.

Minor Pedicle  Branches of facial artery
REGIONAL SOURCE  External carotid artery.
LENGTH  1 to 2 cm.
DIAMETER  0.5 mm.
LOCATION  The facial artery runs on the superficial surface of the masseter muscle. It crosses the body of the mandible approximately a third the distance from the angle toward the mentum.

Venous Anatomy

Accompanying paired veins with the named arteries.

Nerve Supply

Motor  Masseteric nerve, a branch of the mandibular division of the trigeminal nerve.
**Vascular Anatomy of the Masseter Flap**

**Fig. 5F-2**  
A, Masseter muscle in situ with facial vessels visible crossing the mandibular line medially; these vessels give minor blood supply to the muscle.  
B, The muscle is elevated off the mandible to demonstrate the dominant maxillary blood supply.  
C, Closeup of the maxillary pedicle.
Exposure of the Masseteric Nerve

Although exposure of the masseteric nerve is not required for muscle rotations, the nerve is commonly dissected and exposed for use as a motor input for free flap facial reanimation, or “babysitting” procedures after facial nerve injury. The origin of the nerve is found by palpating the mandibular notch, below the zygomatic arch and 2 to 3 cm anterior to the tragus. Exposure is accomplished by exposing the SMAS that overlies the area.

Next a triangular flap of the SMAS is elevated over the notch, exposing the superficial belly of the masseter muscle.
The masseter is composed of three distinct muscle bellies. The masseteric nerve is located between the middle and deep muscle bellies.

Dissection proceeds by removing the superficial muscle belly, exposing the middle muscle belly.

Further dissection carefully removes the middle muscle belly, exposing the nerve. The course of the nerve is oblique, running from the notch toward the commissure of the mouth.
The masseteric nerve may have from one to four branches; 75% of cases have more than one branch. This nerve redundancy or remaining function from the contralateral muscle and temporalis muscles allows sacrifice without compromising mastication.

**FLAP HARVEST**

**Design and Markings**

The masseter muscle can be accessed through a curvilinear incision just below the mandibular angle and the body of the mandible. When used for facial reanimation and reanimation of the commissure, a counterincision is made in the nasolabial area for insertion and placement of the muscle. Forced biting allows the masseter to be palpated and its origins and insertions marked. The muscle is generally used with its blood supply proximal and is released from the mandible. The muscle, based inferiorly, has been used for intraoral reconstruction, although this is uncommon.

![Incision and Facial access incisions](image)

**Fig. 5F-4**

**Patient Positioning**

Supine with the head turned is the most common position for use of the masseter muscle flap.
GUIDE TO FLAP DISSECTION

For the standard, superiorly based flap, an incision is made along the mandibular border in the area over the masseter muscle.

As the dissection is deepened through the subcutaneous tissues, the facial artery and vein are identified. These are not critical for supply of a superiorly based flap but are helpful in identifying the marginal mandibular branch of the facial nerve, which needs to be protected during this dissection. Often this muscle is used in a patient with facial palsy, and this point is moot. The muscle can then be used in part or in whole.
If only a portion of the muscle is to be used, the inferior portion of the muscle is marked and the muscle is released from its mandibular insertion. It is recommended in order to obtain good purchase with sutures that some periosteum is taken as well at this time. If the muscle is being used for reanimation, a tunnel has been made in the subcutaneous plane from the counter incision at the commissure and nasolabial fold. The muscle is passed through this incision and then secured through a series of sutures to the area of the commissure.

**FLAP VARIANT**

**Inferiorly Based Flap**

The successful use of an inferiorly based maseter muscle flap has been reported for intraoral defects and areas of exposure in the mouth. Presumably, the muscle is being carried on branches of the facial artery; therefore these need to be spared during the dissection. Although successful cases have been reported, this is not a first-line muscle for these small reconstructions, because a functional muscle is being sacrificed.

**ARC OF ROTATION**

The masseter muscle is a short, thick muscle that does reach the area of the commissure without extensions required. It would also reach intraorally for potential applications of wound coverage in the mouth. The muscle does not reach to the midline nor beyond the tonsil.
FLAP TRANSFER
The masseter muscle reaches the commissure through a subcutaneous tunnel dissected between the neck incision and the nasolabial incision.

FLAP INSET
It is important to maintain the resting length of the muscle when insetting it for a facial reanimation. The muscle acts by both statically positioning the commissure as well as adding a functional muscle moving the commissure. Because of the excess bulk in the cheek from movement of the masseter, some recommend excision of the buccal fat pad to alleviate this excess. This can be performed through an intraoral or extraoral approach, avoiding disturbance of any functional facial nerves.

DONOR SITE CLOSURE
Primary closure of the skin is obtained in all cases.

CLINICAL APPLICATIONS
This 57-year-old man underwent left-sided facial reanimation using temporalis transfer only.

Fig. 5F-7  A, The patient is seen before reanimation. B, Postoperatively, the lower lip on the paralyzed side is elevated, creating a substantial asymmetry at maximum smile. (Case courtesy Roger L. Simpson, MD.)
This 48-year-old woman underwent right-sided facial reanimation following resection of an acoustic neuroma. Both temporalis and partial masseter transfers were performed.

![Fig. 5F-8](A, The patient is seen before reanimation. B, Postoperatively, her lower lip has excellent symmetry (slight overcorrection) when she smiles. The maximum depression of the lower lip is medial to the commissure. (Case courtesy Roger L. Simpson, MD.))

This 42-year-old man had partial right-sided facial paralysis caused by Bell’s palsy.

![Fig. 5F-9](A, He had marked limitation of his smile on the right side. A temporalis and partial masseter transfer was performed. B, Note the normal expected downward reanimation of the lower lip in conjunction with excellent excursion of the right commissure and upper lip. He is shown 26 years after surgery. (Case courtesy Roger L. Simpson, MD.))
Pearls and Pitfalls

- The masseter muscle is a secondary choice for facial reanimation with local regional muscle. The temporalis muscle has a greater excursion and therefore more function for this purpose. The masseter muscle is thick and has limited excursion.
- Use of the masseter muscle for intraoral defect reconstruction should always be considered carefully, since a functional muscle would be sacrificed.
- A partial masseter muscle can be a useful adjunct to a temporalis muscle reanimation in that it can help position the commissure and provide some lateral movement to an otherwise vertical or oblique vector.
- Reconstruction of the mandible with a myoosseous masseter flap has been described in a limited number of patients.
- To prevent early dehiscence of the muscle in a functional case, the patient should be on a soft diet without chewing for the first 2 weeks.

EXPERT COMMENTARY

Roger L. Simpson

Indications

The masseter muscle and its innervation play an important role in reanimation of the paralyzed face. The muscle, innervated by the masseteric nerve (mandibular division of the trigeminal), is well suited to partial or complete transfer to the commissure and/or lower lip. Both the masseteric artery (branch of the external carotid) and the masseteric motor nerve enter deep to the muscle at its mid to upper portion, making the muscle suitable for a complete or partial 90-degree transfer. Its redundancy in mastication allows transfer without compromising jaw motion or strength.

My concern with the masseter muscle as a stand-alone muscle transfer for facial paralysis is in the direction and the amount of excursion when transferred to the commissure on the paralyzed side. The muscle is 8 by 8 cm, and although a complete 90-degree rotation maintains the integrity of the innervation, it does not permit enough excursion through contraction to move the commissure adequately in comparison to the normal side. Its direction after rotation creates a horizontally directed pull, not taking into account the mixed upward component of the levator labii superioris muscle.

The masseter muscle transfer plays its best role in contiguous regional muscle reanimation as a complement of the temporalis transfer. The temporalis, extended by its fascia, is transferred to the paralyzed commissure and the upper lip in a smooth, continuous fashion. The strength of the temporalis will overcorrect the commissure in an upward direction. Transfer of the anterior portion of the masseter to the lateral aspect of the lower lip just anterior to the commissure will produce an active depression of the lower lip while providing a downward, stabilizing force balancing the commissure. The masseter muscle transfer serves to reproduce the active depression of the lower lip lost in paralysis.
Fig. 5F-10  A, The anterior third of the masseter muscle acts as a complement to help balance the upward-directed pull of the temporalis transfer. Insertion of the masseter medial to the commissure stabilizes the lower lip position with a slight downward pull, re-creating lower lip depression. B, Strong overcorrection of the upper lip and commissure through the temporalis transfer distorts the position of the lower lip in an upward direction. The partial masseter transfer is essential in reproducing lower lip balance.

**Recommendations**

**Technique**

Technically, the masseter is exposed through a 2 cm incision parallel to and below the angle and body of the mandible. The bony groove of the mandible is palpated, allowing identification of the facial artery and the marginal mandibular nerve. The anterior half of the muscle is incised in a cephalad direction until a 90-degree arc of rotation is comfortably achieved. The muscle has a very thin fascia superficially and is often too short for direct suture to the lower lip. Extension with a portion of harvested fascia allows proper tension and a downward and lateral trajectory to the lower lip, ideal for reanimation.

The combination of two muscle transfers to the paralyzed lips creates an excellent balance of forces to produce a symmetrical smile. The dynamic excursion of the partial masseter transfer to the lower lip is occasionally less than expected. The retained attachment may then serve as a sufficiently strong static force tethering the upper temporalis pull.

The motor nerve to the masseter muscle is an excellent innervation for free muscle transfer in facial paralysis reanimation. Manktelow et al\(^1\) described 45 single-stage microvascular transfers of the gracilis muscle to the masseteric nerve, resulting in a high percentage of patients with a spontaneous smile, with a high degree of patient satisfaction. Zuker et al\(^2\) performed staged, segmental gracilis transfers to masseter motor nerves in children with Möbius syndrome, with excellent outcomes.

Klebuc\(^3\) has reported his results in facial paralysis reanimation using direct microsurgical transfer of the descending branch of the masseteric nerve to selected buccal and zygomatic branches of the ipsilateral facial nerve in patients with acquired paralysis. The use of a consistently present masseteric nerve bifurcation allowed direct nerve transfer without an interposition graft. Selective use of a portion of the nerve diminished the risk of masseter atrophy while providing good restoration of facial muscle excursion.  

*Continued*
This technique has been used in conjunction with cross-face nerve grafting to restore the upper face in paralysis.

**Take-Away Messages**

The masseter muscle and its innervation are important anatomic structures in reanimation of the paralyzed face. The versatility of the muscle based on its deep blood supply and innervation allows complete or partial transfer to the commissural region, either directly or by fascial extension to more medial portions of the upper and lower lips. Partial transfer of the masseter through fascial extension to the lower lip is an excellent complement to a strong temporalis transfer to the commissure and upper lip. As a stand-alone transfer, it can provide dynamic depression of the lower lip to restore lost function from a marginal mandibular nerve injury.

Use of the masseter motor nerve, either complete or partial via the descending branch, has shown excellent results in trigeminal-innervated restoration of facial motion either through partial gracilis transfer or through direct innervation of ipsilateral buccal and/or zygomatic branches of the facial nerve.

**References**


**Bibliography With Key Annotations**


The authors reported their results reconstructing 22 defects after resection of retromolar and/or anterior facial pillar squamous cell carcinomas. In 12 patients they used a superiorly based or crossover masseter muscle flap, and in 10 patients they performed an island muscle flap (a modification of the first type). Both techniques offered a quick and reliable method for repairing oropharyngeal defects in oncologically “safe” cases. Elaborate technique or aftercare was not required. The island masseter muscle flap has advantages over the superiorly based masseteric flap of being more flexible and pliable for larger defects, with no postoperative trismus.


To better understand the role of the temporalis muscle in delayed collapse or relapse after reduction of fractures of the zygomatic complex, the authors studied the origins of the temporalis muscle in six cadaveric dissections. In all dissections, the temporalis muscle origin was not only from the floor of the temporal fossa and temporalis fascia, but also from the lateral margin of the orbit and the frontal process of the zygomatic bone as far down as the body of the zygoma. The authors postulated that the functional forces exerted by this muscle on the zygomatic complex cause postoperative distraction at the frontozygomatic suture. These findings support the belief that internal fixation of all fractures
of the zygomatic complex is important, even for those considered clinically stable, to avoid permanent flattening of the cheekbone.


Moebius syndrome is a rare congenital disorder that involves multiple cranial nerves. It is identified predominantly as a bilateral or unilateral paralysis of the facial and abducens nerves. The authors reported on results of 12 pediatric patients with Moebius and Moebius-like syndromes treated by microsurgical reconstruction for restoration of facial movement. The contralateral facial nerve was used as a motor donor nerve in four procedures, the motor nerve to the masseter muscle in eight patients, and the gracilis muscle was used in all operations, for a total of 17 free muscle transplantations. All free-muscle transplantations survived. Drooling, drinking, speech, and facial animation improved significantly, and patients reported a high degree of satisfaction.


The authors shared their results from eight patients with unilateral facial paralysis who underwent gracilis muscle transfer with reinnervation by the motor nerve to the masseter muscle. All free muscle transplantations survived, and no flaps were lost. Facial symmetry at rest and while smiling was excellent or good in all patients. Speech and oral competence were significantly improved. With practice, the majority of patients developed the ability to smile spontaneously and without jaw movement. The authors concluded that the masseter motor nerve is a powerful and reliable donor nerve that facilitates commissure and upper lip movement. The masseter motor nerve may offer appropriate innervation for patients with unilateral facial paralysis who would otherwise be considered candidates for cross-facial nerve graft innervation of the muscle transfer.


Improved facial support and symmetry with volitional movement can sometimes be achieved with dynamic muscle transfer. This is most commonly used for reanimation of the oral commissure to produce a smile. Muscle transfers have been used successfully to reestablish eye closure. Facial paralysis of long-standing duration presents different challenges from paralysis that is managed early after onset. Dynamic muscle transfers are typically performed in these patients. In this respect, the alternative is free tissue transfer. The author described advantages and disadvantages of these two procedures.


Several methods have been employed to restore function of the facial nerve. These include ipsilateral nerve grafting, cross-facial nerve grafting, and temporal muscle flaps or even free muscle transfers. None of these techniques uses the masseteric nerve. This preliminary report discussed the anatomic basis, which could lead to a new technique. The authors studied 36 cases. They found that the masseteric nerve leaves the infratemporal fossa through the mandibular notch, accompanied by the masseteric artery. It was accompanied by only 1 branch in 9 cases, by 2 branches in 17 cases, by 3 branches in 9 cases, and by 4 branches in 1 case. The masseteric nerve should be considered a possible donor for at least the orbicular branch of the facial nerve for the following reasons: (1) the approach to the mandibular notch is quite simple; (2) the nerve consists of two or more branches in 75% of the cases; therefore severe dysfunction of the masseter muscle should not occur; and (3) for complete denervation of the masseter muscle, its function may be assumed by the temporalis muscle.


The authors performed gracilis functioning free muscle transplantation (FFMT) in 249 patients with facial paralysis at Chang Gung Memorial Hospital. Most cases were caused by postoperative complications and Bell’s palsy. The innervating nerve comes mostly from contralateral facial nerve branches, a few from the ipsilateral facial nerve as a consequence of tumor ablation, and from the ipsilateral motor branch to masseter or spinal accessory nerve because of Moebius syndrome. The authors used a short
nerve graft (10 to 15 cm) to cross the face in the first stage; after a 6- to 9-month waiting period, a gracilis FFMT was performed for the second stage of the reconstruction. Results were encouraging.


This article focused on the treatment of a 64-year-old man who underwent full-thickness repair of a cheek defect involving the oral commissure after excision of a squamous cell carcinoma. A cheek skin flap combined with split masseter muscle transposition was performed. This method was useful for reconstructing the oral commissure, with good functional and aesthetic results.


This study assessed the ability of the masseter motor nerve–innervated microneurovascular muscle transfer to produce an effective smile in adult patients with bilateral and unilateral facial paralysis. The operation consisted of a one-stage microneurovascular transfer of a portion of the gracilis muscle that is innervated with the masseter motor nerve. The muscle was inserted into the cheek and attached to the mouth to produce a smile. The outcomes assessed were the amount of movement of the transferred muscle; the aesthetic quality of the smile; the control, use, and spontaneity of the smile; and the functional effects on eating, drinking, and speech. The study included 27 patients aged 16 to 61 years who received 45 muscle transfers. In all 45 muscle transfers, movement developed. A spontaneous smile, the ability to smile without thinking about it, occurred routinely in 59% and occasionally in 29% of patients; 85% of patients learned to smile without biting. Age did not affect the degree of spontaneity of smiling or the patient’s ability to smile without biting.


Dynamic procedures such as muscle transplantation or muscle transposition are required for long-standing complete and irreversible facial palsy. The authors presented their results of regional muscle transposition for reconstruction of eye closure and smile in patients with irreversible facial palsy; 29 were treated by temporalis transposition for the eye, and 8 were treated by masseter transposition for the mouth. Assessment of the outcome was based on clinical examination and evaluation of facial movements by three-dimensional video analysis. Their findings demonstrated that muscle transposition improves static symmetry and provides dynamic activity to a certain degree. It is therefore a valuable concept for patients with limited life expectancy.


In cases of facial asymmetry with denervation atrophy of the masticatory muscles associated with head and neck tumors involving the trigeminal nerve, facial contour depression occurs selectively over the temple and masseteric area, separated by an uninvolved area over the zygomatic arch. The authors developed a new thoracodorsal artery perforator flap with two separate adiposal paddles based on their own perforators from the same mother vessel, the thoracodorsal vessel. Nearly normal temporomasseteric contour was achieved in two patients. By freely positioning two adiposal paddles supplied by independent perforators based on the same vessel, separate noncontiguous regions of the face could be reconstructed correctly with one microneurovascular anastomosis in a single-stage operation, without the need for a secondary procedure to reduce the bulk over the zygomatic arch.


The authors described a case of a 75-year-old man with a squamous cell carcinoma that had originated from the right external ear 4 years previously. He had undergone surgical removal of the lesion with a combination of modified neck dissection and reconstruction with the use of a pectoralis major flap. Furthermore, he had had radiation therapy with 6000 rads to the right temporal region. Two months
before presentation, the patient developed an extended recurrence in the temporal muscle and bone, lophoidal bone, masseter and pterygoid muscles, the right part of the mandible, the parotid gland with the facial nerve, and the superior bulb of the internal jugular vein. The lesion was removed surgically with extended healthy margins, and functional and aesthetic reconstruction of the defect was performed with a combination of metal fixed prosthesis of the condyle and the right mandible and a myocutaneous trapezius flap. This case report underscored the reconstruction options available to provide quality of life in cancer patients.


The temporalis muscle flap can be used as an interpositional graft placed into a gap arthroplasty site in temporomandibular joint (TMJ) ankylosis. The authors investigated the role of the muscle graft in sheep. Five purebred adult Merino sheep were used, and ankylosis was induced in all right TMJs. At 3 months, the ankylosis was released by gap arthroplasty and reconstructed with a masseter muscle graft, because the temporalis muscle is short and poorly vascularized in sheep. The sheep were killed 3 months after muscle grafting. Maximal mouth opening was recorded before and after operation and at death. The joints were examined radiologically and histologically. In 4 sheep, mouth opening remained at the preoperative level. A clear radiolucent space remained between the smooth temporal and ramus stumps. Histologically, the muscle graft remained vital but with some fibrous tissue formation between the bone ends. One sheep developed an infection at the operative site following the muscle graft; this partly resolved with antibiotics, but the TMJ developed a fibrous reankylosis that was demonstrated clinically, radiologically, and histologically. These results indicate that an uncomplicated temporalis muscle graft reconstruction with gap arthroplasty is a successful and stable procedure in human TMJ ankylosis.


The authors reported a new way of reanimating the face involving transposition of the masseter muscle combined with the tensor fascia lata and using the zygomatic arch as a trochea to reconstruct an inferior facial paralysis. They used the technique on five patients who had facial palsy after excision of malignant parotid tumors. The wide skin defect that exposed the masseter muscle after total parotidectomy was reconstructed with a free flap. This method differs from those of other methods of transposing the masseter muscle in that force is applied at an upper lateral angle. The method provided dynamic raising of the upper lip, the corner of the mouth, and the nasolabial fold in four patients. The authors considered the technique to be useful, particularly for prompt surgical reconstruction of facial palsy after total parotidectomy with a wide defect in the skin of the cheek.
ANATOMIC LANDMARKS

**Landmarks**
Circumferential muscle encompassing the upper and lower lips.

**Size**
1.5 × 8 cm.

**Origin**
Multiple origins from other facial muscles and retaining ligaments.

**Insertion**
Lip skin and mucosa.

**Function**
Oral sphincter, oral competence.

**Composition**
Myocutaneous, myomucocutaneous.

**Flap Type**
Type III.

**Dominant Pedicles**
Superior labial artery; inferior labial artery.

**Nerve Supply**
*Motor:* Facial nerve. *Sensory:* Upper lip, superior labial branches of the trigeminal nerve, maxillary division; lower lip, buccal nerve and medial branches of the inferior labial nerve (mandibular division of trigeminal nerve).
Section 5G

HEAD AND NECK

Orbicularis Oris Flap

CLINICAL APPLICATIONS

Regional Use
- Lip
- Chin
- Cheek
- Nose

Specialized Use
- Lip and oral sphincter reconstruction
ANATOMY OF THE ORBICULARIS ORIS FLAP

A

Perioral muscles

B

Course of superior and inferior labial vessels and facial nerve branches

Fig. 5G-1

Dominant pedicles: Superior labial artery; inferior labial artery
ANATOMY

Landmarks Circular muscle encompasses the upper and lower lip.
Composition Myocutaneous, myomucocutaneous.
Size 1.5 × 8 cm.
Origin Surrounding facial musculatures and retaining ligaments.
Insertion Lip skin and mucosa.
Function Oral sphincter and oral competence.

Arterial Anatomy (Type III)

Dominant Pedicle  *Superior labial artery*

**REGIONAL SOURCE** Facial artery.
**LENGTH** 6 cm.
**DIAMETER** 1 mm.
**LOCATION** The lateral border of the muscle at the angle of the mouth.

Dominant Pedicle (Lower Lip)  *Inferior labial artery*

**REGIONAL SOURCE** Facial artery.
**LENGTH** 6 cm.
**DIAMETER** 1 mm.
**LOCATION** Lateral border of the muscle at the angle of the mouth.

Venous Anatomy

Venous drainage is through accompanying venae comitantes.

Nerve Supply

Motor Facial nerve.
Sensory Upper lip, superior labial branches of maxillary division of the trigeminal nerve; lower lip, buccal nerve and the medial branches of the labial nerve, both branches of the mandibular branch of the trigeminal nerve.
VASCULAR ANATOMY OF THE ORBICULARIS ORIS FLAP

LOWER THIRD FACIAL SKIN AND PERIORAL MUSCULATURE

Fig. 5G-2

Dominant pedicles: Superior labial artery (D1); inferior labial artery (D2)

f, Facial artery
LOWLER LIP ABBÉ FLAP

Cutaneous surface of flap

Radiographic view of cutaneous surface

Fig. 5G-2
FLAP HARVEST

Design and Markings
Because of the specialized nature of the orbicularis oris muscle and specialized lip tissues, reconstruction of lip deformities is difficult. When possible, reconstructive flaps based from other lip segments are desirable, because this will often give the most functional and best cosmetic result. Approximately 25% of the upper lip and 30% of the lower lip can be sacrificed without functional significance. For reconstruction, this sacrifice comes in the form of a flap. The five basic flaps a reconstructive surgeon should have in his or her arsenal for this region are the Abbé, Estlander, Gillies fan, McGregor, and Karapandzic flaps. The choice of flap is based on the location and size of the defect to be reconstructed. Each flap can be used for both upper and lower lip reconstruction. Flap designs are as follows.

Abbé Flap
In designing an Abbé flap, the surgeon should take into account the subunit of the chin and try not to cross the chin pad. Also, since the pedicle of the Abbé flap must stay intact for 2 weeks, a pedicle that lies more lateral is easier for the patient to tolerate than a pedicle that crosses in the middle of the mouth.

Estlander Flap
The Estlander flap is essentially an Abbé flap but is positioned adjacent to the defect. This flap is a good option in cases in which the commissure has been sacrificed, and rotation creates a new commissure.
Gillies Flap
The Gillies flap, initially described as an extended Estlander flap, was designed for closure of large lower lip defects (over 50% of the lower lip). Although this flap maintains the commissure, it does reduce the oral opening and moves the commissure medially. It is best used for partial medial defects.

McGregor Flap
The McGregor flap is a variation of the Gillies flap, designed to reconstruct larger defects with loss of vermilion. It maintains the commissure in its proper position and uses cheek skin and subcutaneous tissue to replace the lower lip substance. A mucosal graft or flap is still required to replace missing lip skin and mucosa.
Karapandzic Flap
The Karapandzic flap was also designed for large lip defects and can be performed unilaterally or bilaterally. An advantage of the Karapandzic flap is that it maintains the neurovascular elements to the lip, so the oral sphincter maintains its function. The drawback to this technique is the resultant microstomia.

Patient Positioning
The patient is placed in a supine position.

GUIDE TO FLAP DISSECTION

Abbé Flap
Once the flap has been designed on either the upper or lower lip, the surgeon decides which labial vessel will supply the flap. This decision is based on pedicle location and the strength of the Doppler signal while occluding the contralateral vessel. An incision is then made on the side opposite the source vessel. Dissection proceeds down through skin, muscle, and mucosa as a full-thickness incision, dividing the lip. The surgeon locates the labial vessel and cauterizes it. This is a good reference for dissecting the vessel on the pedicle side. Dissection on the side of the pedicle is made from inferior to superior. When the level of the vermillion is reached, the tissues that are necessary for rotation of the flap are divided. No incision should be made in the skin or mucosa of the lip near this vessel. A handheld Doppler probe can be used to localize the vessel and spare it in the final dissection. One can carefully divide the orbicularis muscle near the pedicle to facilitate flap rotation.
Defect and Abbé flap design

Flap rotated

Flap inset and closure

Cross-section of lip showing labial artery

Fig. 5G-8
**Estlander Flap**

Although the Estlander flap is similar in dissection to the Abbé flap, the vessel supplying the flap is predetermined and will be medial in its position. The side of the flap that faces the wound is freshened, and dissection proceeds along the design laterally, full thickness through skin, muscle, and mucosa. The medial incision is made and stops at the level of the vermilion. The blood vessel is isolated and skeletonized only enough to permit easy transposition.

**Gillies Fan Flap**

For a Gillies fan flap, the incision starts at the level of the defect and is followed around the arc of the mouth superiorly, including skin, muscle, and mucosa, up to the level of the commissure. The remaining incision is only through skin and subcutaneous tissues. A backcut allows rotation and advancement of the flap. One can increase rotation by further extending the backcut and by mobilizing more mucosa. The width of the flap is designed to equal the height of the lip resection. Flap advancement distorts the commissure.
McGregor Flap

The McGregor flap is a modification of the Gillies flap. Whereas the Gillies flap extends laterally in a fan shape, the McGregor modification extends upward vertically in a rectangular shape, with the width of the rectangular flap equal to the vertical height of the lip defect. The vertical length of the flap is equal to the width of the defect plus the width of the flap itself. From the bottom of the lip defect, incisions extend laterally for the full width of the flap and then extend vertically to its full height and medially for the full width. Compared with the Gillies fan flap, the backcut with the McGregor flap is made downward vertically to within a few millimeters of the vermilion border of the remaining lip. The superior labial artery, which supplies the flap, must be preserved. The length of the pedicle and of the flap reach can be increased by extending the backcut and by mobilizing and dividing more mucosa. This flap does not provide mucosa for the vermilion; this must be reconstructed with a free buccal graft, a FAMM flap based on the contralateral side, or a tongue-based flap.

Fig. 5G-11  Design and dissection of the McGregor flap.  
a, Height of lip defect; a’ = a and becomes the new vertical component; b, vertical height of flap that will become the new lip once lined with a mucosal graft or FAMM flap.
The flaps are based on an inferior medial pedicle; they are full-thickness cheek flaps that include the mucosa. Considerable care is required at the pedicle area to avoid traumatizing the vessels around the commissures. A conscious effort is made to maintain a subcutaneous pedicle that is wider than the skin or mucosal pedicle. After the flaps have been incised, they are rotated medially to form the upper lip. The donor defect is closed directly after excision of superior dog-ears of excess skin. The mucosa is reconstructed by advancement. Use of a tongue flap is too hazardous in this situation; it would probably become detached.
Fig. 5G-13  A, Planned resection and flap design. B, Defect with flaps incised. C, Flaps rotated without tension. D, Flaps inset with primary closure of donor sites. E, Bilateral fan flaps provide a lip of adequate bulk; the vermillion is supplied by a tongue flap, which is divided after 2 weeks (see Section 5H). The donor defect can be closed directly without difficulty.
Karapandzic Flap
Of all of the orbicularis oris muscle flap procedures, the Karapandzic flap requires the most meticulous dissection. These flaps are neurovascular flaps; the flap must be mobilized while maintaining the muscle innervation and the vascular pedicle. The planned incisions are made and deepened down through skin to the subcutaneous tissues that follow the nasolabial fold. The orbicularis muscle fibers are then spread apart longitudinally with a scissors in the line of the incision down to the submucosal layer. The nerves and vessels that are encountered are maintained. Mucosa is incised for 1 to 2 cm from the edge of the defect only. To increase the length of the flaps when they do not meet easily, further dissection can be performed in the subcutaneous tissues to allow mobilization, and all nerves and vessels should be preserved.

Fig. 5G-14  A, Karapandzic flap design. B, Arc of orbicularis oris muscle flap and associated subcutaneous tissue with preservation of the neurovascular pedicles. C, Arc of bilateral myocutaneous flap and direct donor site closure.
D, Angular artery supplying the inferior and superior labial artery; n, preserved motor branches of facial nerve
Fig. 5G-15  A, The plan for the procedure is outlined for a carcinoma of the lower lip, consisting of resection followed by reconstruction with bilateral modified Karapandzic flaps. B, The resection is completed. C, Incisions are made transversely from the base of the postexcisional defect on both sides. These extend around the commissures into the upper lip and equidistant from the free lip margin. The orbicularis muscle fibers are spread apart longitudinally, in the line of the skin incision, down to the submucosal layer. The nerves and vessels are maintained intact. The mucosa is incised for 1 to 2 cm from the edge of the defect. D, After this maneuver the edges of the defect can be approximated without tension. E, The lip reconstruction is sutured in layers.
FLAP VARIANTS

- Reverse Abbé flap
- Reverse Estlander flap
- Reverse Karapandžić flap

Each of these flaps is identical to its upper and lower lip variants. The flaps are now based on the opposite lip using the other dominant blood supply to the lip as their nutrient vessel.

ARC OF ROTATION

These flaps are used for lip reconstruction, and the arc of rotation is defined by the reconstructive need. Rotations beyond the subunit of the lip are unnecessary.
FLAP TRANSFER
The Abbé flap is transferred by transposition from one lip to the other. Estlander flap is transferred by transposition from one lip to the other to recreate the commissure. The Gillies flap is transferred by advancement to reconstruct the lip. The commissure is moved more medially and the size of the oral opening is decreased. The McGregor flap is transferred through a combination of advancement and transposition. The vertical height of the flap at the lateral end of the defect becomes the horizontal length of the lip reconstruction. The Karapandzic flap is transferred by advancement of the neurovascular flaps either from one side only or as a bilateral advancement, which is more common.

FLAP INSET
All Flaps
Inset is performed in layers: the muscle layer, the dermal layer, and then the skin layer are all closed, realigning the vermilion for best aesthetics. For the McGregor flap, a secondary procedure is required to add a mucosal surface to the lip to reestablish the vermilion.

DONOR SITE CLOSURE
In all flap modifications, primary closure of the donor site is planned for best overall aesthetics. Each of the flaps takes advantage of the excess in the lip and cheek tissues to allow the advancement and cheating closed of the donor site without excessive tension. With flaps such as the Abbé flap and reverse Abbé flap that require a secondary division and inset, the surgeon must be careful during closure of the primary donor site so that there is not too much tension on the pedicle, which might cause ischemia of the flap. At the time of division and inset, revision of any area that has healed secondarily or any scars of the lips can be performed.
CLINICAL APPLICATIONS
This 50-year-old woman presented to her dermatologist with a pale pink papule, 5 mm in diameter, at the philtrum-columella junction. Biopsy confirmed a Merkel cell tumor. Radical excision was performed using Mohs micrographic surgery, resulting in a full-thickness defect of the upper lip from alar base to alar base transversely and from the tip of the columella below the nasal tip to the white roll centrally. This included the oral mucosa.

Reconstruction was planned in two stages. The first stage involved re-creation of the philtrum and columella with an extended Abbé flap based on the left lower labial artery, while the upper lateral lip elements were to be reconstructed with bilateral perialar crescentic advancement flaps. Two weeks after the first stage was completed, the patient was brought back to the operating room for division and inset of the base of the Abbé flap. Normal contour was restored without requiring revision and the patient was recurrence free two years later.

Fig. 5G-17  A, The patient’s full-thickness upper lip defect is seen after radical resection of a Merkel cell tumor. B, A closeup of the defect shows that it extended from the base of the nasal tip to the white roll. C, Basal view of the columellar defect.
**Fig. 5G-17**  
**D.** Design of the Abbé flap and bilateral perialar crescentic advancement flaps. The shaded areas represent areas of full-thickness skin resection to allow advancement of the perialar flaps.  
**E.** Abbé flap and perialar flaps prepared for advancement.  
**F.** Flaps sutured in place with inset of the Abbé flap.  
**G.** Postoperative staged result 2 weeks before division of the Abbé flap.  
**H.** Final result 1 year postoperatively with no revision. (Case supplied by G.J.)
This 48-year-old smoker with a basal cell carcinoma of the upper lip and cheek had a defect after Mohs surgery that included 50% of his upper lip. The best cosmetic and functional result with a large defect such as this is with an Abbé flap. The cheek flap can be managed with a Mustardé-type cheek advancement.

Fig. 5G-18  A, The defect after Mohs surgery, which extends to the philtrum medially and onto the maxilla superiorly. B, Planned Abbé flap using 25% of the lower lip. C, Lateral view showing the Mustardé flap design and the Abbé design relative to the commissure.
Fig. 5G-18  D, Abbé flap, based on the medial labial artery, rotated superiorly into the defect. E, The flap is rotated and inset. The inset of the cheek flap has also been completed. F, Lateral view of the inset with back-grafting of the cheek to allow cheek rotation. G, AP view at 8 months postoperatively. H, Lateral oblique view. The patient has excellent opening and functional result. He has refused any revisions of his scars. (Case supplied by MRZ.)
This 78-year-old man had a basal cell carcinoma of the upper lip, which was resected using the Mohs technique and reconstructed with Abbé and nasolabial flaps.

Fig. 5G-19  A, The patient's Mohs defect encompassed 70% of the upper lip, some full-thickness, and the ala and columnella of the nose. B, Planned Abbé flap to the central upper lip and columnella and superiorly based nasolabial flap for alar reconstruction. Closure of the nasolabial donor site also allowed some advancement of the commissure medially. C, Abbé rotated and nasolabial flap elevated and ready to inset.
Fig. 5G-19  D, All flaps inset with primary donor site closure. Note how the Abbé donor avoided the chin pad subunit for best aesthetics. E, Lateral oblique view. F, The patient is seen in repose at his 7-month follow-up. Note how normal the scars appear within the nasolabial fold and around the chin pad subunit. G, Lateral oblique view. Without cartilage support, the nasolabial flap to the ala has vanished. H, The patient shows maximal mouth opening, evidencing some microstomia. The patient was functional and desired no further surgery. (Case supplied by MRZ.)
This 42-year-old man had a squamous cell carcinoma of the left commissure requiring resection, which was reconstructed with an Estlander flap.

**Fig. 5G-20**  
A, The patient's Mohs defect encompassed 25% of the lower lip and the left commissure. B, Because he had more upper lip to donate, an Estlander flap was planned from the upper lip to reconstruct the defect and re-create his commissure. C, Flap elevated and rotated into position. D, Inset and donor site closure. Care was taken to avoid tight closure around the pedicle. E, AP view at 1½ years postoperatively. F, Lateral oblique view. Although the patient has been offered commissuroplasty, he is happy with the final result. (Case supplied by MRZ.)
This relatively young woman exhibits an excellent functional and aesthetic result after full-thickness lower lip resection for squamous cell carcinoma and reconstruction with Karapandzic flaps.

**Fig. 5G-21**  
A, Preoperative view.  
B, Proposed resection and flap design.  
C, Defect after resection.  
D, Bilateral Karapandzic flaps elevated.  
E, After flap inset.  
F, The patient is seen 1 year postoperatively.  
G, The patient demonstrates good muscular function of the oral sphincter. (Case courtesy Ian T. Jackson, MD.)
This patient presented with a squamous cell carcinoma of the lower lip infiltrating the muscle. It involved almost two thirds of the lower lip. A McGregor-type fan flap was used to reconstruct the defect.

**Fig. 5G-22**  **A-C,** A full-thickness excision of two thirds of the lip was done, with the lip mucosa resected from the residual third. A unilateral fan flap with a small base of the upper lip that contained the labial vessels was used to reconstruct the defect.
Fig. 5G-22  D and E, The flap is seen rotated into place; note the narrow pedicle. F, The flap was raised from the undersurface of the tongue to increase the length of the tongue flap. G, The donor defect was closed, and the flap provided a nice reconstruction of the lip. H and I, Early and late photographs show that the lip is perfectly adequate in size and shape as well as function. The tongue flap used to reconstruct the lower lip is of a slightly different color and texture compared with the normal upper lip. (Case courtesy Ian T. Jackson, MD.)
This patient presented with carcinoma of the lower lip requiring removal of more than half of his lip. Reconstruction was done with bilateral Karapandzic flaps.

Fig. 5G-23  A, The plan for the procedure was outlined, consisting of resection followed by reconstruction with bilateral modified Karapandzic flaps. B, The resection was completed and the position of the vessels noted. C, The vascular supply to these flaps is well illustrated. This flap can also be made as an island flap.
Incisions were made transversely from the base of the postexcisional defect on both sides. These extended around the commissures into the upper lip; with the use of scissors they were maintained equidistant from the free lip margin. The orbicularis muscle fibers were spread apart longitudinally, in the line of the skin incision, down to the submucosal layer. The nerves and vessels were maintained intact. The mucosa was incised for 1 to 2 cm from the edge of the defect. After this maneuver, the edges of the defect could be approximated without tension. The lip reconstruction was sutured in layers. The result is a competent, sensate, fully functional lower lip with a slightly reduced oral stoma. If necessary, these flaps can be used as islands based on the vessels that supply them. (Case courtesy Ian T. Jackson, MD.)
**Pearls and Pitfalls**

- Ultimately, function of the oral sphincter and size of the oral opening will determine how successful a reconstruction of the lip is. Cases must be individualized to select the best flap for the situation.

- Flaps such as the Abbé, Estlander, Gillies fan, and Karapandzic will reduce the size of the oral opening and may present problems such as microstomia. Rather than leave the patient with a problem such as this when major resection of a lip segment has been performed, one might consider free tissue transfer, which does not supply like tissues, but will allow functional wound closure and will maintain an adequate oral aperture. Free buccal grafts can heal similar to a skin graft and provide a nice mucosal layer to the lip without the morbidity and discomfort of a tongue flap, which must be left in place for up to 2 weeks and then divided and inset.

- Young people without rhytids or aged skin are often poor candidates for reconstruction of large lip defects with local flaps such as the McGregor and Karapandzic flaps.

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**EXPERT COMMENTARY**

**Ian T. Jackson**

**Personal Experience and Insights**

Management of the muscles of the lip is controversial. There are those who advocate subcutaneous suturing, and others who advise freeing of the muscles sufficient enough to perform interdigitation. I prefer the latter, to lengthen the muscles in the repair area. This makes it possible to reduce the amount of vertical shortening. There is also strong tightening of the lower lip. It is my opinion that the muscles of the lip should be repaired accurately in the same position as the noninvolved side. If this is performed very carefully, the repair is more balanced in appearance and in function. This will then result in a more balanced end result.

**Complications and Avoidance**

The most common reasons for flap failure fall into two categories: design fault and technical error. The most common examples of design fault are too small a flap, extending the flap outside its blood supply, and failing to consider previous therapy, such as old scars or areas that have been irradiated. Examples of common technical errors are hematoma, suturing the wound under tension, failing to make a backcut, making the pedicle too short, and damaging the blood supply. Judgment and execution improve with experience, and this lowers the rate of complications. The old adage “measure twice, cut once” underscores the importance of planning to avoid many of the problems above.

**Take-Away Message**

It is important to remember that the lip moves and should move symmetrically.
Bibliography With Key Annotations


Classic article describing the Abbé flap.


A unilateral gate flap technique consisting of a nasolabial island flap was presented for reconstruction of defects in the lower lip after excision of large, laterally located epidermoid tumors. The amount of healthy tissue resected is optimal. The reconstructed lower lip retains sensation and muscle function and is continent with a satisfying appearance. Temporary flap edema and a vermilion notch at the apex of the flap are both avoidable problems. This method may be used in selected patients with large advanced epidermoid cancers of the lower lip.


In two patients, large but superficial partial-thickness resections of lateral upper lip were repaired by composite island cutaneous flaps. Upper lip and nasolabial fold flaps, along with the lateral vermilion, were advanced and closed in a V-Y manner, leaving inconspicuous scars and no contour deformity.


The authors described their experience with reconstruction of lips with the use of innervated myocutaneous flaps. They presented the technique and some illustrative cases.


Repair of a large, trauma-induced partial-thickness vermilion defect is considered a challenging task. Ideally, such defects should be corrected by methods that use tissues similar in color and texture to the normal vermilion. When the length of a defect is greater than half that of the vermilion and the width of the defect is greater than 1.5 cm, however, effective repair is not always achieved using the traditional mucosal V-Y advancement flap. This article described a modified mucosal V-Y advancement flap containing the orbicularis oris muscle. This flap possesses the mobility sufficient to serve as the pedicle for the transfer and repair of large vermilion defects. Between August 2006 and January 2009, vermilion reconstruction using this modified flap was performed on eight patients, with satisfactory cosmetic and functional outcomes obtained in all cases. This simple and useful approach to vermilion reconstruction provides excellent outcomes with minimal injury to the donor site.


Classic description of Karapandzic flap for lip reconstruction.


The authors developed the orbicularis oris myomucosal island flap (OOMMIF) to reconstruct the nasal lining in one stage. The OOMMIF blood supply derives from the intramuscular vascular network, which communicates with the submucosal vascular plexus via the vascular network formed by the deep ascending branches of the superior labial artery. An oral mucosal flap of approximately 2 by 3 cm can be harvested from the upper lip, pedicled solely on the orbicularis oris muscle. They transferred this flap to a nasal lining defect located in the ala in four patients, the nasal floor in two patients, and the columella in two patients. The flap donor site was closed primarily. All flaps took completely
Part II  Regional Flaps: Anatomy and Basic Techniques

with satisfactory results. Minor complications included slight asymmetry of the vermilion height as a result of donor site contracture in one patient, and flap drooping in two patients, corrected by secondary debulking. Upper lip functional loss was not observed, although upper lip hypesthesia occurred in one patient, which disappeared within 6 months. An OOMMIF can be easily elevated with minimal donor site morbidity. Thus the OOMMIF is a good candidate for one-stage reconstruction of small nasal lining defects.


The author described a method for correcting major vermilion defects with a transverse cross-lip vermilion flap. Sizable defects can easily be filled in to obtain an upper lip with better contour and simultaneously reduce the unpleasant fullness of the lower lip, producing better balance between the two lips.


A difficult secondary bilateral cleft lip deformity with nasal distortion was treated with eight local flaps specifically designed for this case. One of these was an Abbé flap in which the coronary vessel in the pedicle was inadvertently divided. The judgment in handling this flap and its fate as a composite lip flap based on a narrow mucosal pedicle is reported.


The lips are a complex, laminated structure. When lost through injury or disease, they present a complex reconstructive challenge. The facial artery myomucosal (FAMM) flap is a composite flap with features similar to those of lip tissue. The authors discussed the anatomy, dissection, and clinical applications for the FAMM flap in lip and vermilion reconstruction and presented a series of 16 FAMM flaps in 13 patients; 7 had upper lip reconstruction and 6 had lower lip reconstruction. Superiorly based FAMM flaps were used in 8 patients, and 8 inferiorly based flaps were performed in 5 patients. Three patients had bilateral inferiorly based flaps. In summary, the FAMM flap is a local flap that can be used for lip and vermilion reconstruction. Although not identical to the lip, it has many similar features that make it an excellent option for lip reconstruction.


By combining the principles of nasolabial and buccal mucosal flaps, the authors designed a new axial musculomucosal flap based on the facial artery. This flap has been designated the facial artery musculomucosal (FAMM) flap. The flap has proved reliable, either superiorly based (retrograde flow) or inferiorly based (antegrade flow). The authors found it versatile and used it 18 times in 15 patients, with 1 failure and 2 partial losses. It has been used successfully to reconstruct a wide variety of difficult oronasal mucosal defects, including defects of the palate, alveolus, nasal septum, antrum, upper and lower lips, floor of the mouth, and soft palate.


Surgical reconstruction of the oral commissure aims to restore both symmetry of the lips at rest and, what is more important, full oral competence. Molding the lip commissure with functional and cosmetic fidelity remains a difficult task. A possible surgical solution, the “elastic flap” principle described by Goldstein, may be found in the wide full-thickness mobilization of the upper and lower vermilion as two composite myocutaneous flaps—tissue sandwiches consisting of labial skin, orbicularis oris muscle and oral mucosa—on the axial pattern of the superior and inferior labial arteries. Based on the contralateral commissure, both flaps are easily stretched, accordion-like, to reach the predetermined point of the new commissure, using to full advantage the inherent elastic potential of both vermilion. The fibers of the orbicularis oris muscle at each end of both flaps are imbricated to reconstitute a neomodiolus, which is anchored to the residual buccinator muscle in primary reconstructions, or to the available perioral fibrous tissue in secondary procedures. The authors presented a select group of 22 patients, who, between 1993 and 2008, underwent this reconstruction procedure for primary or secondary defects involving
the oral commissure. The results were generally satisfactory, both functionally and cosmetically. The advantages of this procedure include full restoration of the dynamic function of the orbicularis ring in a single-stage operation and avoidance of either lip-switching procedures or of mobilization of mucosa and cheek skin. The final scars remain well camouflaged within the oral mucosa and the mucocutaneous junction of each lip.


Various reconstruction techniques using the remaining lip or the adjacent cheek tissue have been described for the repair of lower lip defects. With these techniques, microstomia, commissural distortion, functional insufficiency, and sensorial loss might be observed. The authors described a technique of lower lip reconstruction with preservation of neuromuscular tissue as a single-stage procedure. Lip sensation and orbicularis oris muscle function are preserved. Fifteen patients with lower lip defects, after tumor ablation or after traumatic loss, were treated by this technique. The only prerequisite for the application of this technique is the availability of at least 20% of the remaining lip tissue. Satisfactory functional, aesthetic, and sensorial results were obtained.


The authors described a new way to raise the V-Y advancement flap, which is useful for reconstruction of the lower lip. Various other methods have been reported in the past, but it has been necessary to choose the most suitable method for each case. A V-Y advancement flap from the submandibular region is one of the useful techniques to reconstruct the lower lip and is suitable for a wide horizontal defect. However, the conventional V-Y flap is insufficiently mobile, and the reconstructed vermilion is thin because of the limitation of the pedicle. In such a case, the reconstructed lip may sag or cause an embarrassing defect. The authors developed a new way to raise the flap to obviate these problems by using the V-Y advancement flap from the inferior margin of the defect in a conventional way after excision of the tumor, and using a mucosal flap to reconstruct the vermilion border. The skin side of the V-Y flap is undermined, and the orbicularis oris muscles are preserved on both sides as pedicles. The flap is then raised as a bipedicled myocutaneous flap, which has adequate movement. After the flap has been sutured, the superior margin of the flap is deepithelialized, and used to create the volume of the vermilion border. Functionally and cosmetically good results have been achieved.


Malfunction of the marginal mandibular nerve, either in combination with a generalized facial palsy or in isolation, can cause an unpleasant and disturbing appearance around the mouth. In total palsy, a cross-facial nerve graft combined with a free vascularized muscle transplant will usually correct this problem successfully; however, all older procedures used in this situation are unpredictable. For an isolated palsy, procedures such as digastric muscle transfer or sling suspension are not uniformly successful. The authors described a method using the contralateral, nonaffected lower lip orbicularis muscle. A wedge is removed from the paralyzed lower lip and the orbicularis is advanced to the modiolus to provide a functional orbicularis all the way across the lower lip up to the angle of the mouth. This is a simple outpatient procedure that has produced satisfactory results in most cases.
## ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>This large, specialized muscular structure occupies the floor of the mouth.</th>
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</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>8 cm from tip to foramen cecum × 5 cm transversely is available for flap use.</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>The tongue has five paired extrinsic muscles: (1) genioglossus, (2) hyoglossus, (3) styloglossus, (4) chondroglossus, and (5) glosso-palatinus. These muscles originate from the following structures: the genial tubercle of the mandible, hyoid bone, epiglottis, soft palate, styloid process, pharynx, and the mandible.</td>
</tr>
<tr>
<td><strong>Insertion</strong></td>
<td>The tongue has four intrinsic muscles: (1) longitudinalis superior, (2) longitudinalis inferior, (3) transversus, and (4) verticalis linguae. There is also a fibrous midline septum that extends between the hyoid bone and the tongue base. Extrinsic muscles insert into these structures.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>The tongue is the principal organ of taste and speech and also assists in deglutition and mastication.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Muscle.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type I.</td>
</tr>
<tr>
<td><strong>Dominant Pedicles</strong></td>
<td>Lingual artery, deep lingual artery.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td>Motor: Hypoglossal nerve. Sensory: (1) lingual branch of the trigeminal nerve, (2) chorda tympani branch of the facial nerve, and (3) lingual branch of the glosopharyngeal nerve.</td>
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Section 5H
HEAD AND NECK
Tongue Flap

CLINICAL APPLICATIONS

Regional Use
- Palate
- Tonsil
- Alveolar ridge
- Floor of mouth

Specialized Use
- Upper lip reconstruction
- Lower lip reconstruction
ANATOMY OF THE TONGUE FLAP

A

Palatoglossus muscle
Styloglossus muscle
Stylopharyngeus muscle
Stylohyoid muscle
Middle pharyngeal constrictor muscle
Hyoglossus muscle
Geniohyoid muscle
Genioglossus muscle
Mylohyoid muscle

Lateral tongue muscles

B

Superior longitudinal muscle of tongue
Vertical and transverse muscle of tongue
Inferior longitudinal muscle of tongue
Hyoglossus muscle
Genioglossus muscle
Lingual nerve
Hypoglossal nerve
Hyoid bone

Sublingual salivary gland
Lingual artery
Submandibular salivary gland
Facial artery
Facial vein

Tongue cross-section: Frontal section behind first molar (anterior view)

**Fig. 5H-1**

**Dominant pedicles:** Sublingual artery; deep lingual artery
ANATOMY

Landmarks  The tongue is a specialized muscular structure that occupies the floor of the mouth.
Composition  Muscular.
Size  8 cm from tip to foramen cecum × 5 cm transversely is available for flap use in reconstruction.

GENIOGLOSSUS
Origin  Genial tubercle of the mandible.
Insertion  Inferior fibers to the hyoid bone; middle fibers to the undersurface of the dorsal tongue; superior fibers to the apex of the tongue.
Function  Inferior fibers: protrusion; anterior fibers: retraction; both fibers: depression of the tongue.

HYOGLOSSUS
Origin  The greater coronoid of the hyoid bone.
Insertion  The side of the tongue.
Function  Depression and retraction of the tongue.

STYLOGLOSSUS
Origin  Styloid process.
Insertion  The side of the tongue.
Function  Retraction of the tongue in concert with the genioglossus; elevation of the tongue in concert with the glossopalatinus muscle.
LONGITUDINALIS LINGUEAE
Origin Superior muscle originates from submucosal fibers and the median fibrous raphé at the base of the tongue; inferior muscle originates from the ventral surface of the tongue between the genioglossus and the hyoglossus muscles.
Insertion Apex of the tongue.
Function The superior muscle shortens the tongue and elevates the tip and sides of the tongue; the inferior muscle shortens the tongue and depresses the tip and sides of the tongue.

TRANSVERSUS LINGUEAE
Origin The median fibrous septum.
Insertion The side of the tongue.
Function Narrows and elongates the tongue.

VERTICALIS LINGUEAE
Origin The mucous membrane on the dorsal tongue.
Insertion The ventral surface of the tongue.
Function Flattens and broadens the tongue.

Arterial Anatomy (Type I)
GENIOGLOSSUS
Dominant Pedicle Sublingual artery
REGIONAL SOURCE Lingual artery.

HYOGLOSSUS
Dominant Pedicle Sublingual artery
REGIONAL SOURCE Lingual artery.

STYLOGLOSSUS
Dominant Pedicle Sublingual artery
REGIONAL SOURCE Lingual artery.

LONGITUDINALIS LINGUEAE
Dominant Pedicle Deep lingual artery
REGIONAL SOURCE Lingual artery.

TRANSVERSUS AND VERTICALIS LINGUEAE
Dominant Pedicle Deep lingual artery
REGIONAL SOURCE Lingual artery.
Venous Anatomy
The lingual vein accompanies the lingual artery with venae comitantes accompanying its branches, combining with the facial vein to drain into the internal jugular vein.

Nerve Supply
Motor
Hypoglossal nerve supplies both the extrinsic and intrinsic muscles of the tongue.

Sensory
(1) The lingual branch of the trigeminal nerve (third division, mandibular) provides sensation to the anterior two thirds of the tongue. (2) The chorda tympani of the facial nerve (seventh cranial nerve) located with the lingual nerve provides taste and sensation to the anterior two thirds of the tongue. (3) The lingual branch of the glossopharyngeal nerve (ninth cranial nerve) provides sensation and taste to the posterior third of the tongue.

Vascular Anatomy of the Tongue

Deep surface of the flap (lateral view)  Radiographic view

Fig. 5H-2
Dominant pedicles: Sublingual artery (D1); deep lingual artery (D2)

D1  D2
Lingual artery
**FLAP HARVEST**

**Design and Markings**

Tongue flaps can be based dorsally, laterally, or on the ventral surface of the tongue. Depending on the location of need, both the laterally based and dorsally based tongue flaps can be based anteriorly or posteriorly. By their nature, tongue flaps are two-staged flaps. The first stage involves creation of the flap and attachment to the area of concern, keeping its pedicle intact. The second stage involves division and inset. Care is taken in the design of the flap to avoid critical areas of taste and tactile sensation of the dorsal tongue when possible by using laterally based or ventrally based flaps. All tongue flaps are designed so that the donor site can ultimately be closed primarily. Because of the incredible vascularity of the tongue, Doppler examination is not required for creation of tongue-based flaps.

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**Fig. 5H-3**

- A: Anteriorly based midline flap for palatal defect
- B: Posteriorly based midline flap for palatal defect
- C: Anteriorly based lateral flap for anterior mouth floor defect
- D: Posteriorly based lateral flap for palate and tonsillar fossa
- E: Ventrally based flap
Patient Positioning
The patient is placed in the supine position with a bite block or fixed mouth retractor for best visualization.

GUIDE TO FLAP DISSECTION
Dorsally Based Flap
The dorsally based flap is the one most commonly used for palatal defects because of its proximity. It is not recommended that dorsally based flaps be used for other areas of reconstruction where either a laterally or ventrally based flap will suffice, because the scarring and cosmetic outcomes of the specialized dorsal tissues can be problematic. Once the area to be reconstructed has been debrided and is well defined, the surgeon decides whether an anteriorly or posteriorly based flap will provide the best reach. If either is acceptable, a posteriorly based flap will rely more on anterograde blood flow and will allow better tongue mobility in the interim period before division and inset. Donor site closure is also facilitated. A suture is placed in the tip of the tongue to protrude the tongue, and the midline area of the tongue is then marked, ensuring an adequate base that should measure at least 1.5 to 2 cm. The length should allow ease of rotation and inset. The flap mucosa, submucosa, and superior longitudinalis linguae muscle are elevated for a depth of 5 mm. There is no easily identifiable plane of dissection. Excessively long flaps must be avoided.
Laterally Based Flap

Once the area to be reconstructed has been debrided and is well defined, the surgeon decides whether an anteriorly or posteriorly based flap will provide the best reach. If either is acceptable, a posteriorly based flap will rely more on anterograde blood flow and will allow better tongue mobility in the interim period before division and inset. Donor site closure is also facilitated. A suture is placed in the tip of the tongue to extrude the tongue, and the lateral border of the tongue is then marked, ensuring an adequate base that should measure at least 1.5 to 2 cm. The length should allow ease of rotation and inset. The flap mucosa, submucosa, hyoglossus, superior longitudinalis linguae, and styloglossus muscles are elevated for a depth of 5 mm. There is no easily identifiable plane of dissection.

The posteriorly based flap extends to within 1 cm of the apex of the tongue. The anteriorly based flap extends to the level of the papillae vallata. It is prudent to gradually deepen the flap so that it is 7 mm at its base. Full mobility of the flap can be accomplished by completely incising the mucosa at the base of the flap; however, this is rarely needed and may limit some vascularity to the flap.

![Anteriorly based lateral flap for anterior mouth floor defect](image1)

![Posteriorly based lateral flap for palate and tonsillar fossa](image2)

Fig. 5H-5
Ventral Tongue Flap
The ventral tongue flap is ideal for central defects of the lower lip. Traction sutures are placed in this case, two sutures on either side of the tip of the tongue, to help splay the tongue and present its ventral surface. The flap is designed to be based anteriorly (distally). The design may come to within 1 cm of the tip of the tongue anteriorly. The thickness of the flap is largely determined by the amount of tissue required to reconstruct the lip. The broad base of this flap ensures good viability, and a minimum thickness of 5 mm should be sought.

ARC OF ROTATION
Dorsally Based Tongue Flap
The dorsally based tongue flap will reach the palate with either an anterior or posterior based flap.
Anteriorly Based Lateral Tongue Flap
The anteriorly based lateral tongue flap will reach the lower lip, upper lip, floor of the mouth, alveolar ridge, anterior hard palate, and commissure.

Posteriorly Based Lateral Tongue Flap
The posteriorly based tongue flap reaches the buccal sulcus, cheek, alveolar ridge, tonsillar fossa, posterior hard palate, and posterior soft palate.

Ventral Tongue Flap
The ventral tongue flap will reach the lower lip and anterior floor of the mouth.
FLAP TRANSFER
All Variants
The flap reaches the recipient site by advancement of the ventral flap or by transposition to the recipient site with dorsal and lateral flaps.

FLAP INSET
The flap is directly inset to its recipient site using simple interrupted sutures. Care is taken to avoid excessive tension on the flap.

DONOR SITE CLOSURE
All Flap Variants
Donor sites are partially closed at the first surgery, making certain that the elevated flap is not strangulated. After a minimum of 10 days, the flap is divided at its base and inset into the recipient site. The defect created at the donor site may be closed with a simple absorbable suture. Areas that dehisce or remain open will remucosalize uneventfully.
CLINICAL APPLICATIONS
This 85-year-old woman had a basal cell carcinoma of the lower lip.

Fig. 5H-10  A, Preoperative view of an infiltrative lesion of the lower lip. B, Defect of the lower lip after a Mohs resection. The mistake in planning at this point would be to underestimate the actual bulk of tissue resected and the functional need for adequate replacement. The large size of the overall wound that crosses the anatomic zones of the lip and chin dictates separate handling of each area. C, A ventral tongue flap was chosen and the design drawn for an anteriorly based flap.
Fig. 5H-10  D, The flap was inset to the lip subunit only with extra bulk from the tongue. E, A skin graft was chosen for reconstruction of the chin subunit. A full-thickness graft was taken from the supraclavicular area. F, Appearance of the skin graft and tongue flap 2 weeks later, just before division and inset. G, Appearance immediately after division and inset of the tongue flap. The donor site was closed primarily, and the tongue flap is viable on the lip. H, The patient is seen in repose, 3 months postoperatively. I, View with maximal opening. The patient has excellent postoperative speech, no drooling, and can tolerate a regular diet. (Case supplied by MRZ.)
This patient had a hemangioma of the lower lip that had caused color change and lip enlargement.

**Fig. 5H-11**  **A-D,** The postexcisional defect may be part or all of the length of the lower lip. It consists of mucosa, submucosa, and often a layer of orbicularis. **E-H,** A suture was placed on either side of the tongue, and the required flap was outlined on the undersurface. A flap of the required size was elevated, based anteriorly. The thickness of the flap is that required to reconstruct the lip.
I and J, The posterior edge of the flap was brought forward and sutured to the cutaneous border of the defect and was also sutured laterally. The raw area on the undersurface of the tongue remained, with no attempt at closure. K and L, The tongue flap was left attached to the lip for 10 days and was then divided. At this point it is important to make certain that enough tongue mucosa is transferred to generously close the residual defect. In this way adequate resurfacing is obtained. Failure to transfer sufficient mucosa will result in a thin, pincushioned ridged of tongue mucosa. The incision on the tongue is closed with a continuous absorbable suture. If there is significant induration, causing difficulty in closure, the defect may be left unsutured and will close spontaneously. M, A reasonably normal looking vermilion can be obtained. Scaling of the mucosa because of drying can be seen in this case. (Case courtesy Ian T. Jackson, MD.)
Pearls and Pitfalls

- Careful planning and selection of the vascular base of the flap will help to avoid unnecessary tension and twisting of the flap.
- The tongue is supplied only by the lingual arteries bilaterally. Care must be taken if the patient has had previous neck surgery, such as radical neck dissection, where the lingual artery may have been divided. In these cases one should consider alternative flaps.
- Although dorsally based midline flaps can be attractive for use in visible areas such as the lip, they involve greater morbidity and are more likely to produce tongue deformity and dysarthria.
- The color and texture of the dorsal tongue does not match the color and texture of the lip and remains this way postoperatively. The lateral and ventral surfaces of the tongue, however, can provide an excellent match in both color and texture.
- Closure of the donor site after division and inset is forgiving. It is not uncommon that the area dehisces or is unable to be closed completely. This will remucosalize uneventfully.
- No retaining sutures are required in the interim period before division and inset, other than sutures that inset the flap.
- Tongue mobility and drying of exposed mucosa are common issues during the period of attachment before division and inset, and the patient should be forewarned.
- In a small subset of patients, biting of the flap with incisors can be a potential problem. This can be prevented by using bilateral molar bite blocks. These can be customized to the patient and cemented to the lower molars at the time of surgery.
- Because of the pincushioning and edema that can occur with these flaps, waiting a minimum of 6 months before any surgical revisions is recommended. Revisions of the tongue donor site are rarely required.
EXPERT COMMENTARY

Ian T. Jackson

Personal Experience and Insight

The central anterior–based flap provides a good result in color and texture, but there is pincushioning that tends to settle to a varying degree with time. In my experience, there has never been an indication to provide secondary management of the tongue.

Initially there is the problem of tongue attachment. When indicated, this is divided and patients are so relieved that they are very pleased. They should be told that there will be further improvement in swelling, speech, and competence, but an accurate timetable cannot be given.

Formation of a Cupid’s bow is very difficult. If the bow can be made, it suffers from the deficiency of no white roll, with an artificial-looking junction between the skin and vermilion.

Recommendations

Technique

Upper lip reconstruction places much more tension on the tongue flap than does lower lip reconstruction. Suturing the lateral edges of the tongue to the lip helps to stabilize the reconstruction and prevent separation of the flap. As long as the undersurface of the tongue is used, the color match and mucosal texture are good.

When the defect to be reconstructed includes muscle, a bulkier reconstruction is required and a tongue flap is indicated. Mucosal defects of the commissure can be reconstructed with a tongue flap based anteriorly on the side of the tongue; the flap can be raised and split to be inserted into the anterior portion of the commissural defect. In 10 days the flap is divided and inset into the apex of the commissure. Alternatively, two long posteriorly based flaps from the side of the tongue can be rotated and sutured in the raw areas of the commissure, then divided in 10 days.

Postoperative Care

The lip should be massaged with whatever product the patient finds to be best. Diet is important, so advice from a dietician can be helpful.

Take-Away Messages

For patients, the most important aspect of this somewhat frightening procedure is to have it carefully and fully explained and discussed with the surgeon. A meeting with another patient who has had this procedure can be most reassuring. Patients are told that a degree of drooling and a change in speech are inevitable, but this will improve with time. Be positive. The appearance of the tongue will also improve. A degree of drooling may continue, but this is usually minimal, and again, this improves with time. The surgeon must provide reassurance about the outcome of the surgery, the chances of total cure, and future management of persistent issues if they should arise. Ample time must be set aside for a relaxed question-and-answer discussion.
Bibliography With Key Annotations


Anteriorly based dorsal tongue flaps are the most commonly used flaps for closure of difficult palatal fistulas. The author described a patient in whom the palatal defect was thought to be too big to be closed by the standard tongue flap. The tongue tip was divided into equal dorsal and ventral flaps, and both flaps were used to reconstruct the palatal defect. Technical considerations and advantages and disadvantages of the procedure were discussed.


The tongue provides well-vascularized tissue that can be used predictably in maxillofacial reconstruction. Pertinent surgical anatomy and the different designs and clinical applications of tongue flaps are presented. The authors presented clinical cases.


The tongue flap has been described in reconstructing palatal defects. Nevertheless, properly securing the flap to the palatal defect has continued to pose a challenge, especially because the flap becomes mobile with normal activities (speech and swallow). For this reason, alternative fixation schemes have been discussed in the literature but do not always solve the problem. The authors proposed an alternative method for positioning and securing the tongue flap into the palatal defect. They stated that the advantages of this technique include an increase in flap security and immobility and a decrease in postoperative maxillomandibular fixation requirement. Although unanswered questions still remain regarding improved flap retention with this method, the “parachuting and anchoring” technique provides an alternative method that can most definitely add to the surgeon’s armamentarium.


The authors presented a case report of a 31-year-old woman with bilateral congenital sinuses in her lower lip. A flap from the tip of the tongue was elevated, including mucosa and muscle. The ventral part of the tongue flap was used to reconstruct the vermilion border of the lip and the dorsal portion was used for lining the lower area of the lip. After 3 weeks, the flap was divided. The postoperative period was uneventful in both stages, and the patient demonstrated a satisfactory aesthetic and functional result 4 years postoperatively.


The authors described a surgical technique for and long-term results of lower lip reconstruction with the tongue flap and reviewed five cases in which this technique was used to reconstruct defects of the lower lip, particularly the lip vermilion. All patients were followed for 2 to 10 years (mean 3.4 years). The procedure achieved good functional and aesthetic results, with no major complications, in particular no flap necrosis. One patient complained of paresthesias of the tongue that resolved within 24 months. Speech was unaffected by use of the tongue flap, although eating and drinking were temporarily impaired before flap separation at the second and final stage of surgery. The tongue flap is a simple and reliable technique for reconstruction of part or all of the lip vermilion. The technique is easy to perform and provides good aesthetic and functional results.


The authors described a case series using surgical and prosthodontic modifications of tongue flaps necessary to adapt them for use in the reconstruction of large cleft deformities that were refractory to customary measures using dental implants and to presented their outcomes in patients with complex cleft lip and palate deformities. Five patients were treated with iliac crest bone grafts that were covered by anteriorly based tongue flaps divided at 3 or 4 weeks after surgery. The patients were followed clinically and radiographically for 3 to 12 years after placement of their dental implants to monitor implant survival and success. One of the five patients developed a partial tongue flap detachment, graft dehiscence, and recurrence of an oronasal fistula, which was successfully treated by shifting the tongue flap tissue from its new location in the palate. A total of 18 dental implants were placed into bone-grafted tissue covered by the tongue flaps. There was one implant failure. There were no cases of periimplantitis or bone loss in the 17 surviving implants. Tongue flaps are rarely used clinical entities with a very narrow range of indications. Tongue flaps are useful in the preprosthetic reconstruction of select cases with large residual oronasal fistulas with soft tissue deficits due to scarring from previously failed surgery. Tongue flaps are extremely stressful procedures for patients to endure. Patient selection is of the utmost importance.


A combined tongue flap and V-Y advancement flap were used for reconstruction of the lower lip after radical excision of squamous cell carcinoma in two cases. This V-Y advancement flap is a useful, simple technique, and the orbicularis oris muscle and the branch of the mental artery and nerve can be preserved. The vermillion is reconstructed with a tongue flap, with almost no disturbance in the patients’ speaking or eating and satisfactory cosmetic results.
ANATOMIC LANDMARKS

**Landmarks**

Occupy the submental area, bounded superiorly by the mandibular line and laterally by the angle of mandible. The width of the flap depends on the amount of skin excess.

**Size**

Muscle: 6 × 7 cm; skin: 7 × 15 cm.

**Function**

The platysma muscle that is carried with the flap can be positioned for facial reanimation by maintaining its facial nerve attachment.

**Composition**

Cutaneous, myocutaneous. This is a skin flap that contains a portion of digastric muscle and a portion of platysma muscle.

**Flap Type**

Type C.

**Dominant Pedicle**

Submental artery.

**Nerve Supply**

*Motor:* Cervical branch of the facial nerve (platysma muscle).  
*Sensory:* Transverse cervical nerves. These nerves are not routinely taken with the flap.
Section 5I
HEAD AND NECK
Submental Flap

CLINICAL APPLICATIONS

Regional Use
Head and neck

Distant Use
Head and neck

Specialized Use
Facial reanimation
ANATOMY OF THE SUBMENTAL FLAP

A

Relevant anatomy of submental flap

Marginal mandibular branch of facial nerve

Facial vein

Facial artery

Submental artery

Cervical branch of facial nerve under platysma muscle

Submandibular gland

Platysma

B

Closeup of relevant anatomy of submental flap

Facial artery

Submental artery

Submandibular gland

Platysma

Digastric muscle

C

Inferior view of submental area

Facial vein

Submental artery

Submandibular gland

Facial artery

Digastric muscle

Mylohyoid muscle

Marginal mandibular branch of the facial nerve

Fig. 5I-1

Dominant pedicle: Submental artery
ANATOMY

Landmarks  The flap is bounded superiorly by the mandibular line. A minimum of 1 cm of distance posterior to the mandibular line is recommended to keep the scar hidden under the jawline. The flap can extend all the way to the mandibular angle bilaterally. Beyond this, on the side of its pedicle, more tissue may be taken, but the scar will be noticeable.

Composition  Cutaneous, myocutaneous. This is a skin flap that contains digastric muscle and platysma muscle. The section of platysma taken can be functional if the facial nerve is maintained.

Size  Muscle: 6 × 7 cm (platysma); skin: 7 × 15 cm with primary closure.

Function  When placed properly, the platysma muscle can assist in generalized tone and some reanimation of the face.

Arterial Anatomy (Type C)

Dominant Pedicle  Submental artery

Regional Source  Facial artery.

Length  5 cm.

Diameter  1.5 mm.

Location  The submental artery branches off the facial artery approximately 5 cm away from the origin of the facial artery. The origin of the submental artery is 3 to 5 cm anterior to the angle of the mandible and 7 mm away from the mandibular border. The vessel runs a tortuous course from the facial artery and continues medially, supplying lymph nodes and the submandibular gland. In 70% of cases the artery runs under the digastric muscle, which can be included in the flap. Perforators to the skin can be found on both medial and lateral aspects of the digastric muscle; their dominance is variable between patients.

Venous Anatomy

The venae comitantes of the facial artery are small in diameter. They communicate with the posterior facial vein to form the common facial vein, which drains into the internal jugular vein. The facial vein is 2.5 mm in diameter at its origin. The common facial vein is 3 mm in diameter. There is also a submental vein that is separate from the submental artery and its venae comitantes, and this vein runs a straight course superior and superficial to the submandibular gland and drains into the common facial vein. Because there are valves in the venae comitantes, when a reverse flow flap is performed, it is necessary to incorporate the submental vein for drainage of the flap; it may not be sacrificed without reanastomosis in its new location.

Nerve Supply

Motor  Platysma muscle is innervated by the cervical branch of the facial nerve.

Sensory  Transverse cervical nerves. These nerves are not routinely taken with the flap.
Vascular Anatomy of the Submental Flap

Fig. 5I-2  A, The undersurface of a left-sided submental flap is shown. The dissection plane on the right is subplatysmal until the left digastric muscle is encountered. Perforators on each side of the muscle are investigated. As shown here, both perforators are included by taking the section of digastric muscle within the flap territory. The submandibular gland, an important dissection landmark, is also shown. B, The flap is isolated on the submental vessels, based off the facial vessels. C, The reach of the flap is extended by dividing the facial artery proximal to the take-off of the submental artery. Flow in this "reverse" flap is retrograde through the facial system.

Dominant pedicle: Submental artery (D)
**FLAP HARVEST**

**Design and Markings**

The entire skin paddle of the submental area can be carried on one pedicle, because there is good flow across the midline. The skin design should be a minimum of 1 cm away from the mandibular line to make the scar less noticeable. The thickness of the flap can be determined by flexing the neck and performing a pinch test. Widths of up to 8 cm have been described. In cases in which extra platysma is needed, beyond the skin incisions muscle can be dissected and carried with the flap. In such cases, if innervation is required, dissection must proceed laterally to identify the cervical branch of the facial nerve to be spared.

![Diagram of the submental flap harvest](image)

**Fig. 5I-3** A line 1 cm posterior to the jawline is marked with the patient sitting. The width is determined by the pinch test. The design extends only to the mandibular angles.

**Patient Positioning**

The flap is performed with the patient in the supine position. The neck should not be extended excessively, as is commonly performed with neck dissections, because the head will need to be flexed for closure.
GUIDE TO FLAP DISSECTION

There are three separate approaches to the submental flap: lateral, superior, and inferior. The lateral approach is most commonly used because it allows easy dissection, and, early on, it shows perforators on the contralateral side as a foreshadowing of the ultimate perforators that will carry the flap. Dissection proceeds initially on the contralateral side, where the flap is elevated just below the platysma, and the platysma is taken with the flap. Once the midline is crossed, care must be exercised as the digastric muscles are encountered. Digastric muscles are divided on either side of the flap incisions, and dissection proceeds with identification of the submental artery.

The inferior approach focuses on identification of the submental artery at its branch point from the facial artery. Dissection is deepened through the platysma and down to the submandibular gland. The gland is then retracted inferiorly, showing branches from the submental artery that supply it. These branches are divided. Once the submental artery has been identified, rapid dissection of the rest of the flap can be performed.
The superior approach gives the best exposure for the submental vessel as it takes off from the facial artery. This is facilitated by identification of the facial artery with a Doppler probe, then the facial artery and vein are followed inferiorly to the submental takeoff. This exposure also lends itself to identification of the marginal mandibular branch of the facial nerve, which should be spared. Once the submental vessel has been identified, the remainder of the flap dissection can be performed rapidly.

In all cases, once the flap has been elevated on the submental vessels, the surgeon must decide whether the length of the pedicle is adequate for the reconstructive need. For intraoral and facial uses, the flap is often passed through a tunnel, and the surgeon determines whether there is enough length to perform the reconstructive procedure. The flap can be lengthened by dividing the facial artery just proximal to the takeoff of the submental artery. Flap perfusion is then retrograde through the distal facial artery. In this case, the submental vein must be maintained, because there is poor reverse flow through the venae comitantes of the facial system. If division of the vein is required to add length, a reanastomosis at the site of inset is recommended, either primarily or with a vein graft.
FLAP VARIANTS

- Island flap
- Free flap
- Perforator flap

Island Flap
Island flaps can be useful for reconstruction in the mid to lower face and for intraoral uses. The flap is designed to incorporate the perforator of the submental artery near the digastric muscle. This island of tissue is then attached by a long vascular pedicle that can measure up to 6 cm, allowing placement of the islanded flap within the mid to lower face or intraorally. In males, one must take into account that this area is hair-bearing, which could be problematic for certain reconstructions.

Free Flap
Submental skin is an excellent color and texture match for reconstructions about the head and neck area, especially in elderly patients, because there is excess tissue here. The flap is harvested as described for a pedicle flap. As a free flap, the main vessel of the flap is the facial artery, since it has a longer pedicle length and a more favorable diameter. The facial vein also can be taken to provide a longer pedicle and a larger diameter. This scenario is common when a reconstruction needs to be done on the same side as the cancer resection or previous neck dissection, during which the submental artery and vein may have been divided or made unreliable.

Perforator Flap
The submental flap may be harvested without the digastric muscle. Although there is no functional consequence of taking the muscle, there are times when a thinner flap is preferred, and the muscle does not add to the flap’s blood supply. There is a fair amount of variation in the distribution of perforators, which can be either medial or lateral to the digastric muscle, or both. In a small percentage of patients the submental vessel runs superficial to the digastric muscle belly; in such cases, the flap will already be thin, because the muscle is not taken. When bulk is required for the reconstruction, it is recommended that the digastric muscle be carried with the flap.
**ARC OF ROTATION**

Island flaps can reach the level of the upper cheek and nose. Internally, they can be used for defects of the trachea or pharynx. The arc of rotation can be improved, as noted earlier, by creating a reverse flap, which is based on retrograde flow. This adds an additional 1 to 2 cm to the arc of rotation.

**FLAP TRANSFER**

**Pedicle Flap**

The submental flap as a pedicle flap is transferred through a tunnel to its recipient site for skin resurfacing; this is through a subcutaneous plane. For intraoral or pharyngeal defects, this is often through the operative defect. The surgeon must exercise caution to prevent kinking or tension on the pedicle and damage to the marginal mandibular nerve during creation of the tunnel.

**Free Flap**

Once the flap is harvested and removed to its recipient site, microscopic anastomosis can be performed, and no connecting tunnels are needed.

**FLAP INSET**

**Pedicle Flap**

Care must be taken to ensure that the tunnel has excess capacity and does not constrict the pedicle of the flap in any way. The flap inset should be without tension, and for resurfacing defects of the face, a standard skin closure should be performed. Intraorally and for mucosal defects, the skin may be sutured to the mucosa in watertight fashion.

**Free Flap**

Inset of the flap as a free flap is facilitated by correct sizing of the flap and by some mobilization of the surrounding tissues. The microvascular anastomosis must not be under any tension, and the pedicle must not be kinked.
DONOR SITE CLOSURE

Pedicle Flap

There will be some fullness where the flap is passed over the mandible. The surgeon should not attempt recontouring at the initial procedure for fear of devascularizing the flap. This fullness often settles over time and requires no revision. If it does not settle, revision can be safely performed 4 to 6 months later. Because closure of the neck should be considered an aesthetic undertaking, the skills used for a face lift should be employed. With the neck in a flexed position, it should be possible to perform closure for flaps as wide as 8 cm. Mobilization of the inferior neck above the platysma is safe and will allow a tension-free closure. These neck flaps dissected in this subcutaneous plane have a wide base and are well vascularized. Maintaining the head in a somewhat flexed position postoperatively over the first week will also ensure uneventful healing. Dog-ears should be expected and defatted at the initial flap procedure.

CLINICAL APPLICATIONS

The submental flap is a simple yet versatile regional flap that can be used to reconstruct large defects of the face and especially the cheek. It provides an excellent color and texture match for facial reconstruction, with minimal donor site morbidity. The thin, pliable quality of the skin paddle facilitates reconstruction throughout almost the entire ipsilateral face and oral cavity. In select groups of patients, the submental flap has been used as an alternative to free tissue transfer for reconstruction after resection of orofacial malignancies. Oral function can be satisfactorily preserved postoperatively. An additional advantage, particularly in older patients, is the cosmetic improvement achieved by removing excess submental subcutaneous tissue and skin redundancy.

The submental flap has been used as a functional flap by maintaining innervation to the platysma muscle. The cervical branches of the facial nerve are kept with the flap during elevation. Once the flap is transposed onto the facial defect, the platysma muscle fibers are rotated to provide an upward pull on the oral commissure to assist with facial animation. This innervated platysma myocutaneous flap is an effective way to provide static support and augment facial animation while providing appropriate soft tissue for a moderate-sized, full-thickness facial defect.

Fig. 5I-7  A, This patient underwent a full-thickness excision of a squamous cell carcinoma that included the muscles of facial expression. The flap design is shown.
Fig. 5I-7  B and C, A functional submental flap was elevated and transferred through a subcutaneous tunnel, with the platysma muscle fibers oriented to facilitate facial expression. D and E, The postoperative result after radiation therapy. (Case courtesy Julian J. Pribaz, MD.)
The submental flap can be excellent for reconstruction of buccal defects where resurfacing of the cheek is required. This can often be accomplished as a rotational flap, and no microsurgery need be performed.

Fig. 5I-8  A, This 69-year-old with squamous cell carcinoma of the inner cheek had a large buccal defect. After confirming the size of the defect, a submental flap was designed on the ipsilateral side to allow a pedicle flap to reach the recipient site. B, Flap elevated on the submental pedicle. The dissection across the midline is just below the platysma, and on the pedicle side it included the digastric muscle. The submandibular gland is also seen after its feeding vessels were divided. C, The flap was passed through the subcutaneous tunnel and marked for areas to be de-epithelialized. The flap was then secured to the cheek. D, Flap well healed at 2 weeks postoperatively. E, The donor site scar at 2 weeks. (Case supplied by MRZ.)
There are times when the submental flap is available for reconstruction but is too far to reach as a pedicle. A free flap based on the submental system can be performed to another recipient site on the face.

**Fig. 5I-9**  
A, This 51-year-old man had a poorly differentiated carcinoma of the right cheek. Resection included the anterior maxillary wall and excision of the infraorbital nerve. Because this was close to his eye, it was felt a pedicle submental flap would apply too much downward pressure on the lid, so a free submental flap was performed based on the contralateral pedicle.  
B, The flap was elevated with a nice pedicle length and good perfusion over the midline.  
C, The flap after inset, with anastomosis to the ipsilateral facial artery and vein, effectively lengthening the pedicle. The patient had a protective canthopexy at the initial surgery, underwent two revisions for a debulking cheek lift, and finally, a canthoplasty and placement of a tendon graft for lower lid support.  
D, The final result is seen 1½ years after the initial surgery. (Case supplied by MRZ.)
triumph of technical expertise over clinical judgment. The perforators that would carry this flow at the recipient site for a facial artery–to–facial artery anastomosis. These can often be replanted back into the stump of the facial vessels if the submental is on the same side, a free flap is recommended, still using the submental tissues, but on a contralateral pedicle. When a flap is passed over the mandible for general resurfacing or for intraoral lining, it is helpful for the surgeon to have experience with microsurgical techniques. Even when this flap is performed as a pedicle flap, sometimes a reverse flap is required to gain extra length to perform the reconstruction, and venous anastomosis is required.

In select patients the submental flap may be a good alternative to free tissue transfer for head and neck reconstruction. The hair-bearing nature of the flap in men can be useful for mustache reconstruction although it can be a disadvantage when using the flap in areas such as the nose, where hair–bearing tissues are less desirable.

Because the submental artery supplies cervical lymph nodes, this flap may be used to treat lymphedema.

**EXPERT COMMENTARY**

Michael R. Zenn

**Indications**

The submental flap is one of the most useful for head and neck reconstruction, although most surgeons are not aware of this. Its advantages include having tissues that are well matched in color and texture and its uniform availability in most patients. The submental flap is a first-line choice for resurfacing of the face. It is also uniquely suited for resurfacing of buccal mucosal defects by a simple pedicle rotation.

**Recommendations**

**Planning**

As with most flaps, careful planning is essential, and if the submental flap is to be used during an oncologic procedure, one must coordinate harvesting of the flap with the cancer resection so that the blood supply to the flap can be spared during oncologic resection. In cases in which a neck dissection is required because of disease in the neck and the defect is on the same side, a free flap is recommended, still using the submental tissues, but on a contralateral pedicle. These can often be replanted back into the stump of the facial vessels at the recipient site for a facial artery–to–facial artery anastomosis. Although the flap is described as a perforator flap and can be dissected as such, this is a triumph of technical expertise over clinical judgment. The perforators that would carry this flow at the recipient site for a facial artery–to–facial artery anastomosis.

**Pearls and Pitfalls**

- Careful placement of the skin paddle posterior to the mandibular line and staying within the angle of the mandible will provide the best postoperative cosmetic result.
- Flaps more than 8 cm in width may be hard to close. In a younger patient who does not have skin excess, this width may be limited to 5 cm.
- Aggressive and wide undermining of the lower skin flap above the level of the platysma allows tension-free closure.
- In a patient with an intact facial nerve, early identification of the marginal mandibular branch of the facial nerve is critical.
- When a flap is passed over the mandible for general resurfacing or for intraoral lining, it is helpful for the surgeon to have experience with microsurgical techniques. Even when this flap is performed as a pedicle flap, sometimes a reverse flap is required to gain extra length to perform the reconstruction, and venous anastomosis is required.
- In select patients the submental flap may be a good alternative to free tissue transfer for head and neck reconstruction.
- The hair–bearing nature of the flap in men can be useful for mustache reconstruction—although it can be a disadvantage when using the flap in areas such as the nose, where hair–bearing tissues are less desirable.
- Because the submental artery supplies cervical lymph nodes, this flap may be used to treat lymphedema.
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flap are small, and the amount of muscle that is taken to carry all possible perforators is also small; it does not necessarily make the flap bulky. As in most cases of tissue transfer, secondary revisions can be performed if the area needs further contouring. One must stay focused on the matter at hand, which is the reconstruction of a defect with the best possible blood supply.

Technique
Of the three techniques of flap harvest described, I often use a combination of techniques as I surround the pedicle and exclude unnecessary tissues. I uniformly mobilize the lower neck to aid in closure and attempt to make the aesthetic improvement in the neck, one of the bonuses of this procedure for the patient. The remaining scar can be thick and noticeable, and it is important to perform the preoperative marking with the patient in an upright position, using the pen to define the area under the mandible where a scar will not be seen. This is commonly 1 cm back from the mandibular edge. It is unwise to cheat this scar closer to the edge of the mandible to obtain more flap, because it will leave a more noticeable scar.

Complications: Avoidance and Treatment
The main complication related to the use of the submental flap is ischemia. When we read descriptions of the old platysma flap, it is evident that its unreliability stems from the fact that this area is largely supplied by the submental vessel. When attempts were made to carry the platysma outside the area described for a submental flap, there were often problems with ischemia. It is commonly accepted today that use of this flap and the platysma within it is best and is reliably carried by the submental vessels.

Bibliography With Key Annotations

Complex defects resulting from surgical excision of facial cancer sometimes require reconstruction using microvascular free tissue transfer. Tissue transfer from areas distant from the face can resolve many problems, but often provides a poor cosmetic match with facial skin. The submental flap helps surmount this problem. Cervical skin has similarities with facial skin, and because this is a regional flap, it helps eliminate microsurgical risks. The authors reviewed a series of nine cases (eight men and one woman), reviewed the anatomy and surgical technique, and explained the advantages and limitations of the submental flap.


Skin characteristics make the submental region an available flap site for facial and intraoral reconstructions. For this reason, the anatomy of the submental region and the submental artery has gained in importance. The submental artery branches out from the facial artery at the level of superior edge of the submandibular gland. The submental artery runs anteromedially below the mandible and superficial to the mylohyoid muscle. It gives off some perforating branches to the overlying platysma and underlying mylohyoid muscle during its course. The terminal branches continue toward the midline, crossing the anterior belly of digastric muscle either superficially or deep, and end at the mental region in general. Some perforating arteries from the terminal branches supply the anterior belly of digastric muscle. This study described the anatomic features of the submental artery and its branches to help in the preparation of submental arterial flaps.

The authors assessed the vascularity of the platysma muscle by the branches of the facial artery to determine the best means of harvesting a myocutaneous flap while ensuring maximum vascular security. Ten platysma muscles were dissected on four fresh specimens and one formaldehyde-preserved specimen. The dissection was performed after injection of the facial artery in four cases, while four muscles were dissected without any previous injection. The vascular supply of the platysma muscle comes essentially from the branches of the submental artery and from branches descending straight from the facial artery. Other collateral branches contribute to this vascularization, but their importance is minor. All these arteries reach the muscle, entering its visceral aspect, then proceed to the sternal notch in a radial axis. The size of the flap has to be defined within a quadrilateral figure, with its base formed by the mandibular edge and its apex by the inferior limit of the flap. It is essential to preserve the maximum possible muscular thickness, especially on the medial side of the flap. If the facial artery needs to be ligated, this has to be done as it enters the submandibular space to protect most of the collateral branches destined to the muscle. The vascularization is then taken back by the ipsilateral and contralateral facial vascularization in an inverted flow in the remaining segment of the facial artery.


The authors explored the application of submental island flaps in repairing pharyngeal fistula after total laryngectomy. Nine cases of concomitant pharyngeal fistula (including seven cases of laryngeal carcinoma and two cases of hypopharyngeal neoplasms) were repaired with submental island flaps after total laryngectomy. All patients were men, age 52 to 71 years (mean 61.8 years). Pharyngeal fistula occurred 5 to 62 days (mean 14.7 days) after total laryngectomy. The diameter of medial pharyngeal fistula ranged from 1.9 cm to 4.1 cm. All patients failed to respond to conservative therapy for 25 to 46 days. The size of the submental island flap was from 2.5 by 2.4 cm to 4.6 by 4.0 cm. After the pharyngeal fistula was repaired with submental flap, the donor site were sutured directly. All nine flaps survived, and no local necrosis or wound infection occurred. Incisions at the donor site healed by first intention, and no obvious scars formed. A fistula occurred 10 days postoperatively in one patient who had undergone preoperative radiation therapy; the fistula was treated symptomatically. Other patients achieved satisfactory results with a one-stage repair. The gastric tube was removed 14 to 22 days after operation; no patients had a sense of obstruction to swallowing. The patients were followed for 10 to 38 months (mean 27 months). The appearance of the neck was satisfactory.


An 8-year-old boy who was diagnosed with acute nonlymphoblastic leukemia (M2) developed secondary oral maxillofacial necrotic fasciitis. The wound was cleaned with a 3% hypertonic saline solution, and then covered with iodoform gauze every day for about 3 weeks before and after necrotic tissue debridement. The local infection was controlled, and plenty of new healthy granular tissue had grown. When the necrotic tissue was removed, the patient was left with a huge defect, including the floor of the mouth, submental and submandibular area, and right cheek. Reconstruction of the defect was very difficult because of the patient’s preexisting leukemia and severe inflammatory local condition. The authors successfully reconstructed the defect by using the new healthy granular tissue and a trapezius myocutaneous flap. Over 9 years of follow-up to improve his quality of life, the patient underwent scar modification surgery and orthodontic treatment, and facial appearance and oral functions were deemed satisfactory.


This study assessed the reliability of using the reverse facial-submental artery deepithelialized submental island flap for reconstructing facial contour deformities. Reverse facial-submental artery deepithelial-
ized submental island flaps were used for reconstructing facial contour deformities in five patients after ablation of benign tumors. The patients (four women and one man) ranged from 29 to 36 years of age. Recurrent pleomorphic adenoma in the cheek and inferior temple was present in three patients, and recurrent basal cell adenoma was present in one. Adequate reconstruction was achieved in all patients, without flap failures or complications. Satisfactory aesthetics and complete functionality were achieved, and no donor site problems occurred.


Functional and aesthetic restoration in maxillary reconstruction remains a challenge. Although many free flap procedures have become popular in maxillary reconstruction, these microsurgical methods have certain limitations and risks. This study assessed the reliability of the reverse facial artery-submental artery mandibular osteomuscular flap for reconstructing maxillary defects. Eight maxillary defects were repaired following ablation of benign tumors with reverse facial artery-submental artery mandibular osteomuscular flaps. The defects were classified as class 2a. Primary reconstruction of the maxilla was carried out using a pedicled mandibular osteomuscular flap. No flap failures occurred. Dental reconstruction was successful in all patients. Proper aesthetics and complete functionality were achieved, and there were no donor-site problems. The patients were followed for 12 to 24 months, with an average of 18.6 months, and there were no recurrences.


The submental flap was described for head and neck reconstruction more than a decade ago. Its application is confined mainly to nonmalignant diseases or low-grade malignancies, because the submental flap resides in the level I lymphatic drainage region of the neck. The authors reported the use of the submental flap for soft tissue reconstruction in a selected group of patients with aggressive orofacial cancer. From March of 2003 to September of 2005, 10 patients (9 with intraoral squamous cell carcinoma and 1 with facial angiosarcoma) underwent submental flap reconstruction after surgical extirpation of aggressive orofacial malignancies. The indications were severe comorbidity, old age, the presence of another incurable cancer, and/or the patient’s skepticism about undergoing a free flap operation. Of the surviving patients, the median follow-up was 21 months (range 2 to 37 months). There were no cases of total flap failure, but partial necrosis occurred in two cases. Three patients experienced tumor recurrence, but in only one case this might have been related to use of the submental flap. Postoperative oral function—swallowing and speech—was well preserved; conventional dentures were fabricated for four patients. In selected patients with aggressive orofacial cancer, the submental flap is an expedient alternative to free tissue transfer for reconstruction. Nonetheless, indiscriminate use might compromise the oncologic outcome, so it cannot be regarded as a standard method of treatment.


Loss of the mustache and beard in an adult man caused by severe burn, trauma, or tumor resection may cause cosmetic and psychological problems for the patient. Reconstruction of the elements of the face presents difficult and often daunting problems for plastic surgeons. The tissue to be used should have the same characteristics as the facial area, consisting of thin, pliable, hair-bearing tissue with a good color match. Very limited donor sites have these characteristics. A hair-bearing submental island flap was used successfully for mustache and beard reconstruction in 11 men during the past 5 years. The scar was on the mentum in four patients, right cheek in two, right half of the upper lip in two, left cheek in one, left half of the upper lip in one, and both sides of the upper lip in one. The submental island flap is supplied by the submental artery, a branch of the facial artery. The maximum flap size was 13 by 6 cm; and the minimum size was 6 by 3 cm (average 10 by 4 cm) in this series. Direct closure was achieved at all donor sites. Patients were followed for 6 months to 5 years. No major complication was noted, other than one case of temporary palsy of the marginal mandibular branch of the facial nerve. Color and texture matches were good. Hair growth on the flap was normal, and
characteristics of the hair were the same as the intact side of the face in all patients. The submental island flap is safe, rapid, and simple to raise and leaves a well-hidden donor-site scar. The authors stated that the submental artery island flap surpasses the other flaps in reconstruction of the mustache and beard in male patients.


The authors presented their experience with the reversed submental perforator-based island flap for nose reconstruction and their anatomic and clinical studies. There have been several descriptions on the reversed pattern of the submental flap, but its anatomic background and clinical availability are still questionable. The submental area was analyzed by anatomic dissection on four fresh cadavers that were injected with a barium mixture. The anatomic data were accumulated with the authors’ clinical experience, with eight patients treated with a submental island flap. On the basis of these studies, the location of reliable perforators was constant at the lateral and/or medial border of the anterior belly of the digastric muscle, but their locations were not always symmetrical in the submental territory. Unlike the comitant submental vein, another larger superficial vein has a different course before reaching the lateral border of the anterior digastric belly, and therefore it must be included in the reversed flap. The presented anatomic results and the clinical experience prove the reliability of the reversed submental perforator-based island flap as a versatile option in midface reconstruction, including the nose, once the dissection has been carefully done, respecting the anatomic points that can be found in this study.


Perforator flaps have become increasingly popular in reconstructive surgery, because there is less donor site morbidity than with conventional musculocutaneous flaps. Previously, the authors’ laboratory described the intraoperative use of near-infrared fluorescence angiography for patient-specific perforator flap design. This study evaluated the predictive capability of near-infrared fluorescence angiography for flap survival in submental flap reconstruction. Use of near-infrared fluorescence angiography immediately after flap creation accurately predicted areas of perfusion at 72 hours, compared with the initial clinical assessment. Identification of necrosis by histology at 72 hours correlated with near-infrared findings of insufficient arterial perfusion immediately after flap creation. No statistically significant differences in perfusion metrics were detected based on location or dominance of the preserved perforator; however, flaps containing central perforators had a higher percentage perfused area than those with noncentral perforators.


The submental flap is a reliable alternative to microsurgical reconstruction of facial deformities, providing an excellent cosmetic match with the contour and color of the face. In this study, the authors evaluated submental flap design by using near-infrared fluorescence angiography to identify perforator arteries. The impact of the number of preserved perforator arteries on flap perfusion and venous drainage was quantified. Indocyanine green was injected intravenously into 18 pigs. Three groups of six animals each had one, two, or three perforator arteries preserved. The fluorescence-assisted resection and exploration near-infrared fluorescence imaging system was used for image acquisition. Images were recorded before and after flap creation, and every hour, for 6 hours. The time to maximum perfusion, the drainage ratio (an indicator of venous drainage), and the percentage of perfused flap area were analyzed statistically at each time point. Near-infrared fluorescence angiography can reliably identify submental perforator...
arteries for flap design and can be used to assess flap perfusion and venous drainage in real time. Flap metrics at 6 hours were equivalent when either one or multiple perforator arteries were preserved.


This article reviewed the submental island flap, focusing on its relevant surgical anatomy, surgical technique, and recent applications in head and neck reconstruction. The submental island flap is a reliable and versatile flap for head and neck reconstruction. Its minimal donor site morbidity, excellent cosmetic match, pliability, and relative ease of dissection and application has a definite advantage over distant flaps, making it an excellent addition to the reconstructive armamentarium of the head and neck surgeon.


The authors reported their study comparing intraoperative, postoperative, and functional results of submental island pedicled flap (SIPF) with radial forearm free flap (RFFF) reconstruction for tongue and floor-of-mouth reconstruction. The study included 60 patients, 27 with SIPF reconstruction and 33 with RFFF reconstruction. Donor site, flap-related, and other surgical complications were comparable between the groups, as was speech and swallowing function. Reconstruction of oral cavity defects with the SIPF results in shorter operative time and hospitalization without compromising functional outcomes.


The authors described their experience with the submental flap over 10 years. They provided a brief review of the key points and some refinements in the operative technique. The results of 31 patients with a mean age of 57 years were reviewed. All flaps were pedicled except two. One case of composite flap with bone was used. The mean size of the flap was 11.8 by 5.5 cm, and the mean postoperative stay was 11.1 days. Complications encountered were one case of temporary palsy of the marginal mandibular branch of the facial nerve, one hematoma at the recipient site, and two cases of partial flap loss. Color and texture match were good. The authors concluded that this flap has great clinical potential and is a worthwhile addition to the existing surgical armamentarium.


The authors reported on a retrospective study of 21 patients who underwent upper aerodigestive tract reconstruction with submental artery flaps. The flap was used primarily to reconstruct defects after tumor extirpation, severe infections, and burns. In one case, the flap was used to close an esophagecutaneous fistula. Nine patients underwent radiation therapy. Three patients had flap prelamination before transfer. The flaps in all 12 patients who had not undergone irradiation survived. With the exception of a small fistula in one patient and transient marginal mandibular nerve palsy in another, none of these patients had any major complications. In contrast, six of the nine patients who had undergone radiation therapy experienced major complications. These included total flap loss in one, partial flap losses in two, and scar contractures in another three. The difference in major complication rates between these two groups was statistically significant (0% versus 67%). In nonirradiated tissues, the submental artery flap is an excellent choice for reconstruction of moderate-sized defects of the upper aerodigestive tract because of its reliability and versatility and the ease with which it can be applied.


Facial contour augmentation is often encountered by reconstructive surgeons. To date, very different autologous tissues such as fat, dermofat, dermal fascia, muscle, cartilage, and bone in the manner of grafts or flaps according to the requirements of the defect have been used for facial augmentation. Although many free flap procedures have become popular in facial contouring, these microsurgical
methods have some limitations and risks, especially in patients who are not suitable for microsurgery. Moreover, the patient may wish to be treated with a more conservative procedure. The authors used the submental flap in deepithelialized fashion successfully for augmentation of the face in three patients; two had hemifacial microsomia and one had long-standing facial paralysis. Adequate augmentation was achieved in all cases, with no complications. All donor sites were closed primarily and healed well. Patient satisfaction was perfect in all cases. A second debulking procedure was performed in the third case only. The average follow-up was 1 year.


The authors proposed to clarify aspects of the anatomy of the submental flap to improve the utility of this flap. Ten cadavers were injected with a modified lead oxide–gelatin mixture. Four cadavers were selected for three-dimensional reconstruction using a spiral CT scanner and specialized volume-rendering software. Dissection, angiography, and photography of each layer were performed to outline the course of every perforator in the neck. The area of the vascular territory supplied by each source vessel was calculated. Surface areas were measured using Scion Image software. The skin and muscles on the anterior neck and mandible are nourished by several arterial perforators: facial artery, superior thyroid artery, mental artery, lingual artery and the submental artery. The diameter of the submental artery was 1.7 ± 0.4 mm at its origin from the facial artery. It sends 1.8 ± 0.6 perforators to the skin on its course toward the chin. The average size of the territory supplied was 45 ± 10.2 cm². Its largest perforating branch arises from behind the medial border of the anterior belly of the digastric muscle. There were multiple anastomoses between perforators from the submental artery, facial artery and sublingual artery.


The authors presented their study to assess the reliability of the reverse facial artery–submental artery deepithelialized submental island technique to reconstruct maxillary defects. The study included 13 patients (9 men and 4 women; 43 to 62 years of age) with maxillary defects resulting from cancer ablation. Ten patients presented with maxillary gingival squamous cell carcinoma; the remaining 3 cases were hard palate squamous cell carcinomas. The maxilla was resected and the remaining defects were classified as class 2a. Reverse facial artery–submental artery deepithelialized submental island flaps measuring 8 to 10 cm long and 4 to 5 cm wide were used to reconstruct the defects. Twelve of the 13 flaps survived. No donor site problems or palsy of the marginal mandibular branch of the facial nerve occurred. The follow-up period ranged from 8 to 24 months; one patient died as a result of local tumor recurrence, and two patients developed cervical recurrence.


Of all the local flaps that allow elevation of a sufficiently large flap while also leaving an inconspicuous donor site scar, the submental island flap is frequently used for the reconstruction of a defect in the lower two thirds of the face. However, this flap has certain disadvantages: the technique is slightly difficult to
perform and it carries a significant risk of injury to the facial nerve. The authors proposed the reverse facial artery flap, elevated from the submandibular region. Their method creates a flap that includes only the platysma under the skin island, without either the submental or facial artery. However, above the superior border of the skin island, the flap includes the facial artery along with subcutaneous soft tissue. The blood circulation of the skin island is in a random pattern and that of the subcutaneous pedicle is in an axial pattern. The authors presented four cases treated with this method. There were no complications cases, and the results were also cosmetically very good. The authors stated that compared with the submental island flap, their method is easier to perform and carries a much lower risk of damage to the marginal mandibular branch of the facial nerve, because the facial artery crosses over the facial nerve at only one point. In addition, the method produces a thin flap.

You YH, Chen WL, Wang YP, et al. Reverse facial–submental artery island flap for the reconstruction of maxillary defects after cancer ablation. J Craniofac Surg 20:2217-2220, 2009. This study assessed the reliability of the reverse facial–submental artery island flap for reconstructing maxillary defects. Twelve patients (nine men and three women) with cancer underwent surgical resection and sequential maxillary reconstruction using a reverse facial-submental artery island flap. No flaps failed. There were no donor site problems. The patients were followed for 16 to 30 months; there was one local recurrence of tumor. The reverse facial–submental artery island flap is safe, quick, and simple to elevate. The flap can be used reliably for reconstructing maxillary defects.

Zhang B, Wang JG, Chen WL, et al. Reverse facial-submental artery island flap for reconstruction of oropharyngeal defects following intermediate stage and advanced-stage carcinoma ablation. Br J Oral Maxillofac Surg 49:194-197, 2011. To assess the reliability of the reverse facial–submental artery island flap for reconstruction of oropharyngeal defects after resection of intermediate stage and advanced carcinomas, the authors studied 13 patients with stage III and IV squamous cell carcinoma of the oropharynx. All tumors had been excised, followed by reconstruction of the oropharyngeal defect using a facial-submental artery island flap. There were no major flap failures, but two minor ones. The marginal mandibular branch of the facial nerve remained intact and undamaged in all cases. All donor sites healed well, and the scars were well hidden. The functional results of speech and swallowing after 10 to 28 months’ follow-up were satisfactory. One patient developed lung metastases. The facial–submental artery island flap is a simple, reliable flap that can be used for reconstructing oropharyngeal defects after resection of medium and advanced carcinomas of the oropharynx.
ANATOMIC LANDMARKS

Landmarks: Buccal mucosa overlying the course of the facial artery.

Size: 2 × 8 cm.

Function: Mucosal lining.

Composition: Mucosa, myomucosa.

Dominant Pedicle: Facial artery, angular branch.

Minor Pedicles: Superior labial artery, infraorbital artery.
Section 5J

HEAD AND NECK

Facial Artery Myomucosal (FAMM) Flap

CLINICAL APPLICATIONS

Regional Use
- Head and neck
- Palate
- Alveolus
- Nasal lining
- Maxillary antrum
- Tonsillar fossa
- Soft palate
- Floor of mouth
- Lip

Specialized Use
- Nasal reconstruction
- Lip reconstruction
Fig. 5J-1

**Dominant pedicle:** Facial artery  
**Minor pedicle:** Superior labial artery
ANATOMY

Landmarks  
Buccal mucosa overlying the course of the facial artery.

Composition  
Buccal mucosa, submucosa, buccinator muscle. The muscle that is taken with the flap is not functional.

Size  
2 × 8 cm.

Function  
Mucosal lining.

Arterial Anatomy

Dominant Pedicle  
Facial artery, angular branch

Regional Source  
External carotid.

Length  
4 cm.

Diameter  
2.5 mm.

Location  
Crosses the inferior border of the mandible within 3 cm of the mandibular angle. Follows a tortuous course toward the alar base but lies superficial to the buccinator and the levator anguli oris. It lies deep to the risorius, zygomatic major, and the orbicularis oris muscles and supplies perforating vessels to the cheek and gives off the superior labial artery. It continues as the angular artery and ends near the medial canthus, where it communicates with the infraorbital artery.

Minor Pedicle  
Superior labial artery

Regional Source  
Facial artery.

Length  
1 cm.

Diameter  
0.3 mm.

Location  
Upper lip.

Minor Pedicle  
Infraorbital artery

Regional Source  
Maxillary artery.

Length  
1 cm.

Diameter  
0.2 mm.

Location  
Midpupillary line of the maxilla.

Venous Anatomy

Accompanying venous plexus with the facial artery and angular artery. Diameter of the facial vein at its origin is 3 mm.

Nerve Supply

There is no functional muscle and no sensory nerve taken with the flap.
**FLAP HARVEST**

**Design and Markings**

The facial artery myomucosal (FAMM) flap is an axial flap based on the facial artery as it courses from the mandible to the medial canthus. The facial artery lies between the buccinator muscle and the overlying muscles of facial expression. Therefore, to harvest buccal mucosa with the facial artery, a section of the buccinator muscle must be taken. The flap thus consists of mucosa, submucosa, and buccinator muscle and is 5 to 8 mm thick. The flap may be used as a superiorly based flap or an inferiorly based flap.

![Inferiorly based flap design](image)

![Superiorly based flap design](image)

**Fig. 5J-2**

The superiorly based flap is based on the retrograde flow through the angular artery, which is a continuation of the facial artery. The inferiorly based flap is based on the facial artery and its angular artery extension. Some vascularization of the flap probably comes superiorly from the infraorbital artery and inferiorly from the superior labial artery and its branches. Which design is selected, inferiorly based or superiorly based, depends on the intended application. Although both flaps are commonly used for lip reconstruction, the superiorly based flap can be used for reconstruction of the palate, alveolus, nasal lining, maxillary antrum, soft palate, and floor of the mouth. The inferior flap may be used for the floor of the mouth, lower lip, and lower jaw.

Marking of the flap begins with Doppler ultrasound examination to identify the course of the facial artery. It is helpful to think of the FAMM flap as the mirror image of a nasolabial flap in its direction and vascularization. The designed flap is then centered over the facial artery with its orientation oblique, extending from the retromolar trigone to the labial sulcus near the alar margin. The course of the facial artery is anterior to Stensen’s duct, and care should be taken to avoid injuring it during the dissection.

**Patient Positioning**

The patient is placed in the supine position.
GUIDE TO FLAP DISSECTION

A superiorly based flap dissection begins inferiorly by incising the mucosa, submucosa, and buccinator on either side of the facial artery. It is critical that the artery be included with the flap for proper vascularization. At this inferiormost point the facial artery is identified and ligated. It is useful to maintain some length on this suture to help bowstring the facial artery and ensure its inclusion with the dissected flap. The remainder of the flap is then incised, and dissection proceeds superiorly. Care must be taken to maintain the facial artery within the flap, since the connections between the artery and the mucosa are fairly loose. Once the flap has been elevated completely, it should appear pink and viable.

For an inferiorly based flap, the dissection begins superiorly with identification of the angular artery. Again, mucosa, submucosa, and buccinator division is required to identify the artery. It is then ligated, and dissection proceeds inferiorly toward the base of the facial artery, which has been identified by Doppler ultrasound. Inferiorly the facial artery diverges from the mucosa, and care must be taken to maintain its connection for proper vascularization of the flap. The facial vein can be seen lateral to the facial artery at the base of the flap.
ARC OF ROTATION

Superiorly Based Flap
A superiorly based flap may be used to reconstruct defects of the hard palate, alveolus, maxillary antrum, upper lip, and even the orbit.

Inferiorly Based Flap
An inferiorly based flap may be used to reconstruct defects of the hard palate, soft palate, tonsillar fossa, alveolus, floor of the mouth, and lower lip.
FLAP TRANSFER

Both Variants

The surgeon must exercise care when transposing the flap to its recipient site so there is no excessive tension. In addition, the mucosal tissues must not be separated from the underlying facial artery, which has a loose connection. When reconstructing the palate, the surgeon must carefully plan transposition of the flap to avoid the dentition. In patients being treated for wide cleft palates, there is often a gap in the alveolar ridge that can be used to allow a superiorly based flap access to reconstruct the defect. When dentition is intact, an inferiorly based flap is more commonly used. In that case, a temporary bite block is necessary, as well as a secondary division and inset.

FLAP INSET

Tension-free closure is essential for the success of a FAMM flap. An interrupted suture is normally used—nonabsorbable for lip reconstruction, and absorbable for intraoral and nasal reconstruction.

DONOR SITE CLOSURE

Direct donor site closure can be done easily, because an area of excess is used for the flap. At the base of the flap, the closure must be loose and not compromise the vascular pedicle. Any areas of intraoral dehiscence can be managed conservatively and allowed to heal by secondary intention.

CLINICAL APPLICATIONS

This 12-year-old patient had a complex bilateral cleft lip and palate. A FAMM flap was planned.

Fig. 5J-6  A, An alveolar gap allowed a superiorly based flap to be raised to traverse from cheek to palate without risk of injury from the teeth. B, The flap was dissected, as described in the chapter. It was fairly thick and well perfused to its distal tip. The dissection was continued as far as necessary to transpose the flap into the defect. C, At the palatal defect, local turn-in flaps were used for nasal lining and then the flap was positioned to restore the oral coverage. (Case courtesy Julian J. Pribaz, MD.)
This case demonstrates upper vermilion reconstruction. This patient had a *forme fruste* type of hemifacial microsomia with a deficiency of the right upper lip vermilion. He had undergone several unsuccessful procedures to attempt to add bulk.

Fig. 5J-7  
A, The patient is seen preoperatively. B and C, A contralateral superiorly based FAMM flap was raised and inset into the defect. The incision was made at the junction between the wet and dry mucosa, allowing the rim of dry mucosa to rotate externally and the flap to be inset at this junction. D, The postoperative result is shown. (Case courtesy Julian J. Pribaz, MD.)
With intact dentition, it is not possible to use the FAMM flap as a superiorly based flap, because the pedicle would have to traverse the dentition, which would result in injury to the pedicle when the patient bit down. Designing this as an inferiorly based flap and transferring this flap around the retromolar area is an alternative strategy that can result in a satisfactory outcome. Even so, the flap tends to be rather thick at its base, and a bite block may require a two-stage procedure. This case illustrates a way of repairing this defect in a single stage.

Fig. 5J-8  
A, The patient had a complex palatal defect and intact dentition. B, A one-stage procedure was achieved by raising an additional flap that extended from the base of the FAMM flap in the retromolar area to near the margin of the defect itself. C, The flap was based on blood supply through its base, and thus was raised to within 1 cm of the palatal fistula and turned over to repair the nasal lining. The residual donor defect creates a large furrow to accommodate the transposition of the inferiorly based FAMM flap so that it no longer protrudes and is not at risk from injury when the patient bites down. D, The result is shown 6 months postoperatively. (Case courtesy Julian J. Pribaz, MD.)
This 64-year-old man had a squamous cell carcinoma of the lower lip. The loss of volume and vermilion was addressed with an inferiorly based FAMM flap.

Fig. 5J-9  A. The lower lip defect is seen after Mohs excision, with removal of 90% of the lip, along with lip bulk. B, An inferiorly based FAMM flap was planned. A Doppler probe was used intraorally to trace the facial artery's course, and the flap was designed around it. C, The FAMM flap was elevated. Some early sutures were placed near the base to prevent inadvertent pulling on the flap and separation from the artery. The donor site was closed primarily. D, The FAMM flap is seen inset; it is pink and viable. E, One-month postoperative view. The FAMM flap has nicely reestablished the vermilion and replaced some lost bulk in the lower lip. (Case supplied by MRZ.)
This 73-year-old man underwent Mohs resection of two squamous cell carcinomas. Aside from skin of the cheek and commissure, he had lost lower lateral bulk and vermilion. A V-Y advancement flap was used to address the skin defect, and the lip was reconstructed with an inferiorly based FAMM flap.

**Fig. 5J-10**  
A, The defect consisted of a superficial upper lip defect, a deeper complex defect of the commissure, and 50% of the lower lip.  
B, A FAMM flap was planned for the lower lip defect. A Doppler probe was used intraorally to show the course of the facial artery and angular branch. The flap was then planned around this.  
C, The inferiorly based FAMM flap was raised. Some distal sutures were placed to prevent separation of the mucosal surface from the artery.  
D, The FAMM flap was inset, reestablishing the vermilion and providing appropriate bulk. The upper lip defect was grafted with a full-thickness, hair-bearing graft from the submental area, and the commissure and associated defect was reconstructed with a V-Y advancement flap.  
E, The patient is seen in repose at his 3-month follow-up with a good aesthetic result. The skin graft is already growing hair; the V-Y advancement flap still has some pincushioning, but the FAMM flap has already settled nicely.  
F, With the mouth opened slightly, one can appreciate the added bulk and the color and texture difference between oral mucosa and normal vermilion. The patient was happy with the result and requested no revisions. (Case supplied by MRZ.)
Pearls and Pitfalls

- The FAMM flap is an excellent choice for replacement of lip mucosa in lip reconstruction.
- One-stage reconstruction can be accomplished for lip reconstruction, which can be advantageous compared with the two stages that are necessary with Abbé flaps and tongue flaps.
- Although the buccinator muscle is harvested with the flap, no facial weakness has been detected postoperatively.
- Maintaining the proper plane of dissection should avoid injury to the facial nerve, whose branches lie directly beneath the facial artery during dissection.
- In some cases in which simple resurfacing of the lip is required, a free buccal graft may be more effective than a FAMM flap, which can add unnecessary bulk to the lip.
- Intraorally, a FAMM flap is preferred to skin flaps; the mucosalized surface better replaces like with like and avoids such issues as hair growth and desquamation.
- Sometimes FAMM flaps can be bright red and shiny compared with the normal lip and can benefit from laser treatment to reduce this difference.

EXPERT COMMENTARY

Julian J. Pribaz

Indications

The FAMM flap is an extremely useful and versatile flap with a wide range of possible applications within the oral and nasal cavities. As a superiorly based flap, it can be used to reconstruct small defects of the hard palate, alveolus, and upper lip (both the sulcus and the vermilion). It can also be used for antral defects of the maxilla and to restore nasal lining. As an inferiorly based flap, it can be used to reconstruct defects of the soft palate, and, with modifications, the hard palate, as well as the tonsillar fossa, alveolus, tongue, floor of the mouth, and lower lip vermilion and sulcus.

Advantages and Limitations

The advantage of the FAMM flap is that it uses local tissue to reconstruct local defects, thereby permitting a like-with-like restoration. A limitation of this flap is its size. Although larger flaps can be designed based on the facial artery, secondary donor site problems such as contractures may arise in the cheek, so the use of flaps that are too wide is precluded.

Anatomic Considerations

The relevant anatomy has been well described in this chapter, but I would like to further emphasize the importance of ensuring maximal axially of this flap by including the facial artery along its entire length. In addition, because there is no large obvious comitant vein accompanying the artery, but mainly an extensive but tiny venous plexus throughout the flap, it is important to leave some soft tissue around the base of the flap to ensure adequate venous drainage. This flap should never be skeletonized on its facial artery alone, because this will become venous congested and fail poorly.
Recommendations
Planning
As described in the chapter, it is essential to map out the course of the facial artery. This can be done both on the outside of the cheek and intraorally, with an awareness that the facial artery has a tortuous course. It will be noted that the facial artery runs in a course from the angle of the mandible toward the oral commissure and then up toward the alar base. It gives off both the inferior and superior labial vessels and has a connection to branches of the transverse facial artery. It passes anterior to Stensen's duct. A long flap with a maximum width of about 1.5 to 2 cm can be designed based either superiorly or inferiorly. Again, the key is to locate the facial artery, which is just deep to the buccinator muscle.

Technique
The operation commences at the distal end of the flap by cutting through mucosa, submucosa, and buccinator muscle, and then the artery is located. The artery may also be located near the oral commissure by cutting through the same layers, carefully dissecting out the facial artery, and following it in a retrograde fashion to the distalmost part of the flap. Once this is done, the distal parts of the flap can be incised and the flap elevated, taking care to leave the tenuous attachments between the facial artery and its overlying buccinator and submucosa or mucosa intact.

The small terminal branches of the facial nerves will be seen, and these can be gently dissected away, leaving them intact. There is always some degree of postoperative swelling after this procedure, which makes it difficult initially to assess the facial muscle mobility, but once the swelling subsides, I have not found any obvious facial nerve weakness.

Postoperative Care
The postoperative course is fairly simple, with regular mouth washes and a soft diet initially, advancing this over the first week. Complications may arise with the use of larger flaps, because this may result in some tightness in the cheek after repair, and may require release of the contracture with Z-plasty once everything is healed. Also, when the flap is used for palatal reconstruction or for nasal airway reconstruction, the thickness at the base of the flap may necessitate some revision to divide and inset the flap to restore the natural contours of the alveolus, or in the case of the nose, to correct any nasal airway obstruction caused by the bulk at the base of the flap as it transits from the oral cavity into the nasal cavity. Again, I would like to reemphasize that it is essential to have the facial artery traverse the length of this long, thin flap to avoid ischemia at the distal tip.

Bibliography With Key Annotations

Vermilion reconstruction was traditionally performed using buccal mucosa from the lip and cheek or mucosa from the tongue. In this article, the authors presented a case in which a 20-year-old woman with a 4.5 by 1.5 cm elliptical vermilion mucosal defect underwent reconstruction with a labia minora graft. The inner leaf of the labia minora was used, because the tissue closely matches lip color. The underside of the graft was shaved to remove subcutaneous tissue and sebaceous glands. The graft was successful, with excellent return of sensation. The author discussed the technique and advantages of using this tissue.


The authors performed the FAMM flap in 22 patients having wide, scarred, recurrent palatal fistulas. The patients ranged in age from 2 to 21 years. All patients with cleft palate had undergone previous surgery. A bilateral FAMM flap was used in one patient. Two flaps had partial necrosis and one failed completely, probably because of twisting of the whole pedicle. The nasal lining was made using turnout flaps of the fistula margin. Because of hanging the base of the flap (inferiorly based) and producing bite block during mastication, the pedicle was divided and the flap inset secondarily 1 month later.


The authors reviewed their experience with 61 FAMM flaps used for floor of mouth reconstruction after cancer ablation to assess the flap’s reliability, associated complications, and functional results. There were 15 cases of partial necrosis and no total flap loss. Eight other complications occurred. Ten percent required revision surgery; 85% resumed a regular diet; 93% had functional and/or understandable speech, as determined by the surgeon; and 83% had successful dental restoration.


Reconstructing lips lost as a result of injury or disease is a complex reconstructive challenge. The FAMM flap, harvested from the lateral cheek, is a composite flap and an excellent option for lip and vermilion reconstruction. The authors reviewed the literature and presented their experience using this flap successfully in a 2-year-old girl with medial lower lip vermilion avulsion.


The authors studied the facial regions in 14 cadavers and compared their findings with descriptions published in the anatomic literature. Their results are presented. They also performed the buccinator muscle mucosal flap in 38 patients—24 to close primary cleft palates that required palate lengthening, 12 to close palatal fistulas, one to treat a mandibular osteitis, and one to repair the palate after tumor resection. Three small fistulas were reported.


Technical caveats and pitfalls of the buccinator myomucosal island pedicle flap were presented, based on cadaver studies and clinical cases. A relatively large amount of vascularized mucosa can be introduced into the oral cavity via this flap.


Oral-antral-nasal (OAN) fistula is a common clinical problem. Numerous publications are available that describe closure of a persistent OAN. Minor to moderate defects can be closed using local flaps. Larger fistulas present more challenging reconstructions. The authors described a method using an anteriorly based buccinator myomucosal island pedicle flap for reconstructing the oral cavity. An extensive literature review, the anatomy of the buccinator, its reconstructive capabilities, and two case reports were discussed.


Reconstruction after resection of a large oropharyngeal tumour poses a difficult challenge. The authors presented a case illustrating an extension of the previously described FAMM flap, whereby a defect
of the soft palate is replaced with a similar trilaminar structure in the form of irradiated, redundant lower lip. This allows not only the treatment of the palatal defect, but also management of dribbling secondary to a marginal mandibular palsy.


Wegener’s granulomatosis is a progressive disease that leads to saddle-nose deformity. The authors presented their experience reconstructing this deformity in a 45-year-old man with quiescent Wegener’s granulomatosis. A costal cartilage graft fashioned as struts and used to provide dorsal and columellar support. Bilateral FAMM flaps were used to replace nasal lining. Three months postoperatively, a debulking procedure was performed. Donor sites healed uneventfully, and there was no facial nerve weakness. The authors discussed flaps previously used for this purpose and the advantages of FAMM flaps in this setting.


The FAMM flap was first described in 1992. The long rotational arc of this flap is particularly suitable for anterior palatal defects that are otherwise difficult to treat with local flaps. However, after the first clinical reports, some controversies arose about the reliability of this flap, so the authors conducted an anatomic study of the vascular pattern with a latex preparation in 10 cadavers. They studied the variations of the course of the facial artery and focused on the relationship between the facial artery and vein within the pedicle. They concluded that the flap is more an arterialized flap than an axial-pattern flap, and have given anatomic landmarks to optimize the survival rate. Their preliminary clinical results (five good results, one complete failure) are acceptable.


Several fresh surgical defects of the maxillary alveolus, palate, and tonsillar area, resulting from the excision of cancer, were repaired in a single operation by pulling through an inferiorly based nasolabial flap with a subcutaneous pedicle. Patient rehabilitation was rapid.


The author presented observations on 96 dissections of human parotid glands, noting the incidence, size, location, and histologic features of accessory parotid glands. Twenty-one percent of the dissections revealed clearly detached accessory glands at variable distances from the main gland. There were no appreciable histopathologic differences between the accessory gland and the main gland in the same facial half. Aging changes, such as decreased glandular elements, increased fat, and increased fibrous connective tissue, were not more extensive in the accessory gland than in the main gland. Because of the histologic similarity, pathologies of the main gland could also involve the accessory parotid gland. Failure to remove a distantly separated accessory gland during parotidectomy could be a cause of tumor recurrence. Radiographs and sialograms were examined for the accessory parotid glands and their ducts. Routine diagnostic radiographs were limited in their usefulness, whereas sialograms provided visualization of accessory glands for diagnostic purposes.


The authors discussed the use of the inferiorly based FAMM flap to repair a defect of the mandibular vestibule and the advantages and disadvantages of this procedure. The FAMM flap effectively covers
defects of the mandibular vestibule and other regions of the oral cavity, and its softness, toughness, and minimal shrinkage allow the use of dental prostheses.


The FAMM flap was studied in six patients with large symptomatic nasal septal defects measuring at least 20 mm in their greatest dimension and related symptoms of nasal crusting, discharge, dryness, obstruction, epistaxis, pain, or whistling. Causes of septal perforation included blunt trauma, cocaine abuse, and submucous resection. Ages ranged from 21 to 44 years. Follow-up ranged from 10 to 30 months. Septal perforations ranged in size from 3.1 to 4 cm. At the last follow-up, all patients had closure of their septal defect. The overall discomfort score was 0 (range 1 to 10) for all patients, and all had complete resolution of symptoms. This single-stage technique resulted in no visible external scar and minimal donor site morbidity.


Soft tissue defects of the lower lip may be amenable to reconstruction with the sliding door flap raised on the surface of the vermilion to the oral mucosa. The bilateral inferior labial artery nourishes this flap. Bilateral flaps allow safe, easy transfer of the vermilion tissue to partial defects of the red lip. These flaps have been used successfully in patients with lower lip defects. The sliding door flap has increased mobility by at least 1 cm more than the other style of flap reported by Goldstein. Moreover, this flap contributes to excellent cosmetic results. The authors presented their technique and clinical experience using this flap.


The FAMM flap is technically a combination of the nasolabial flap and buccal mucosal flap. It has been a reliable, versatile flap, either superiorly or inferiorly based, for reconstructing a wide variety of intraoral mucosal defects resulting after cancer excision, including defects of the palate, alveolus, lips and floor of mouth. The authors performed 17 flaps in 16 patients. There were no failures, and one flap had terminal necrosis. Most flaps developed venous congestion that resolved with conservative management.


The author described a method to correct major vermilion defects using a transverse, cross lip vermilion flap. With this technique, large defects were easily filled to improve upper lip contour and reduce unpleasant lower lip fullness.


The authors reconstructed 12 lip-shave defects (three were extended) using orbicularis oris myomucosal flaps. They described planning a V-Y plasty for myomucosal advancement and presented some results.


An anterior hard palate fistula for which more than one attempt at repair using local tissue has failed is a difficult complication in cleft surgery. Before alveolar bone grafting, cleft patients have an open anterior maxillary arch that allows passage of a pedicled flap from cheek to hard palate. The superiorly based FAMM flap passed through the deflected alveolus is one of the newer techniques to solve this difficult problem. The authors assessed the validity of using a FAMM flap with an anterosuperiorly based pedicle with retrograde blood flow to correct a large anterior hard palate fistula when a lack of adequate local soft tissue precludes a local flap closure, and the patient otherwise would need a tongue
flap. They performed 16 FAMM flaps in 14 children. Twelve were successful, two had partial flap loss following venous congestion, and two had complete flap failure. One small wound dehiscence occurred, resulting in a small posterior fistula. The authors concluded that this flap obviates the need for a staged tongue flap repair for patients with an open maxillary arch.


For patients with a severely burned lip, both reconstitution of the tissue bulk and an increase in size of the vermilion may be required. The authors performed a bipedicled lip flap in two patients to transpose both bulk and vermilion from the relatively normal donor lip to the atrophic burned lip. They discussed their results.


In addition to closing the cleft palate, cleft palate surgery is performed to push back the palate by repositioning the levator muscle to ensure normal speech. This pushback operation is an effective method for velopharyngeal closure; however, postoperative fistula can occur, especially when the cleft palate is wide. Postoperative maxillary deformity can also result, possibly because elevating the mucoperiosteal palatal flap is extremely troublesome. To push back the nasal mucosa, the authors applied the Kaplan buccal flap method, which is also applicable for reestablishing the levator muscle sling. The other buccal flap was covered on the hinged flap of the pared cleft margins. This resulted in far less maxillary growth disturbance. The authors called it the T-shaped buccal flap method and applied it in more than 30 patients with various cleft palates. Their results were satisfactory.


The advantages of the FAMM flap for reconstruction of midface defects have been well appreciated since 1992, when the flap was first described. In this article, the authors presented their results using this flap to reconstruct a large palatal defect in a 61-year-old woman. She had undergone excision of a recurrent histiocytoma. A modified inferiorly based FAMM flap supplied by the left facial artery was utilized. A medially based mucoperiosteal flap provided nasal lining. No revisions were required. The authors discussed their technique and reasons for choosing it.


The authors performed an extensive review of literature pertaining to the repair of upper and lower lip defects. They found that the many procedures used today had already been developed by the middle of the nineteenth century. There is little that can be defined as original after that time. Most of the so-called new methods for labial reconstruction are modifications of old ideas. The authors emphasized that only a few concepts should be regarded as decisive to achieve a good final result. The use of lip tissue to repair lip defects should be one of the aims of modern cheiloplasty. Following this principle, it is possible to reestablish interrupted sphincteric functions of the orbicularis oris and, simultaneously, most of the expression of emotions. When insufficient material is available for reconstruction, full-thickness local cheek flaps can be considered the alternative solution.


The authors dissected 50 facial arteries in 25 adult, preserved cadavers and presented anatomic variations. The facial artery was symmetrical in 17 dissections. It terminated as an angular facial artery in 34 cases, as a lateral nasal vessel in 13, as a superior labial vessel in 2, and in 1, the artery terminated at the alar base. Five facial arteries had a longer course. They discussed the use of a nasolabial flap (skin, full-thickness, and oral mucosa) raised as an island flap based on the facial artery or one of its branches.

The authors reconstructed a defect of nearly the entire lower vermilion using a buccal myomucosal flap following resection of a malignant tumor of the lower lip. Results were satisfactory. The flap was semispindle shaped and pedicled at the angle of the mouth. A flap as large as 1.5 by 5 cm could be raised while ensuring that fibers of the buccinator muscle extended over its entire length. Reconstruction with this technique is a two-stage operation, and a secondary, minor touch-up operation is performed on the angle of the mouth at the same time the dog-ear of the pedicle is repaired. Postoperative drooling is minimized with this flap, and food can be taken orally soon after this operation. Hemodynamics are maintained, because the flap contains fibers of the buccinator muscle. Aesthetically, the vermilion is given a natural eminence and its sensation returns early postoperatively.


The authors studied the vascular anatomy of the perioral region in fresh cadaver dissections. The anatomy of perioral branches of the facial artery consistently confirmed the existence of a septal branch and an alar branch to the upper lip, and a vertical labiomental branch to the lower lip. New regional flaps supplied by these perioral arterial branches were proposed. The mucosal flap from the upper lip supplied by the deep septal branch or the alar branch of facial artery can be used to restore lower lip defects. A composite flap from the lower lip supplied by the vertical labiomental branch of the facial artery can be used safely to restore combined defects of the upper lip and nose or partial defects of the lower lip.


A series of 16 FAMM flaps in 13 patients was presented. Seven patients had upper lip reconstruction, and six had lower lip reconstruction. Superiorly based FAMM flaps were used in eight patients, and eight inferiorly based flaps were performed in five patients. Three patients had bilateral, inferiorly based flaps. The FAMM flap is a local flap that can be used safely to restore combined defects of the upper lip and nose or partial defects of the lower lip.


This paper introduced the authors’ FAMM flap, combining the principles of nasolabial and buccal mucosal flaps. The flap has proved reliable either superiorly based (retrograde flow) or inferiorly based (antegrade flow). It was used 18 times in 15 patients. One flap failed, and two had partial loss. It was used successfully to reconstruct a wide variety of difficult oronasal mucosal defects, including defects of the palate, alveolus, nasal septum, antrum, upper and lower lips, floor of the mouth, and soft palate.


The author shared his experience using oral mucosal flaps in 18 patients. The viability of the flap was good if drying was prevented and the blood supply enhanced either by muscle inclusion in the pedicle or by insertion into a vascular bed.


The whole lip can be resurfaced with sensate myomucosal flaps taken from the cheeks. These flaps can be combined with major resection of the entire lip curtain. Recovery of sensation was particularly beneficial to elderly patients, who made up the greatest number of patients in the series.


Restoration of symmetry and full oral competence are goals of surgical reconstruction of the oral commissure. The “elastic flap” principle, described by Goldstein, may provide a solution in the wide full-thickness mobilization of the upper and lower vermilion as two composite myocutaneous flaps—tissue sandwiches consisting of labial skin, orbicularis oris muscle and oral mucosa—on the axial pattern of the superior and inferior labial arteries. Based on the contralateral commissure, both flaps are easily stretched in accordion-like fashion, to reach the predetermined point of the new commissure. The fibers
of the orbicularis oris muscle at each end of both flaps are imbricated to reconstitute a neomodiolus, which is anchored to the residual buccinator muscle in primary reconstructions, or to the available perioral fibrous tissue in secondary procedures. The authors presented a select group of 22 patients who underwent this procedure for primary or secondary defects involving the oral commissure. The results were generally satisfactory, both functionally and cosmetically. The advantages of this procedure were discussed.


A one-stage nasolabial island flap isolated on the facial artery and vein was described for floor of mouth reconstruction. The donor site was closed primarily, with acceptable aesthetic results. This was a one-stage procedure. The arterialized flap carried its own blood supply to the irradiated area. In elderly patients, the donor site provided a large amount of redundant skin that stretched easily across the midline or to the roof of the palate. Transient upper lip palsy and drooling occurred for several weeks after surgery.


Large defects of the vermilion border of the lip pose difficult reconstructive problems. Vermilion border deformity and a reduced buccal cavity can result. The authors used bilateral island vermilion flaps pedicled by labial arteries to reconstruct the vermilion border of the lower lip (a modification of Kapetansky's double-pendulum flaps). Their technique was a very reliable and versatile alternative to other local flaps.


In three patients with lip cancer, the authors used a one-stage V-Y advancement method for reconstruction. Without sacrificing the primary principle of adequately removing the cancer, they were able to excise the lesion and reconstruct the defect by means of a subcutaneous pedicle that might otherwise have been discarded with the usual wedge resection. With this method, there is a slight tendency for the healed skin flap to exhibit trapdoor scarring; however, in older patients, in whom this technique has its greatest applicability, this has not been a permanent problem. The technique was easy to perform and resulted in minimal morbidity.


The authors devised a surgical technique for reconstructing the vermilion that used a large portion of the mucosa vestibularis and of the underlying musculus orbicularis. The mucosa and muscle were taken from one lip and rotated to cover the quantitative and qualitative defect of the opposite prolabium. This was achieved in two stages.


Twelve temporoparietal fascial flaps were prefabricated to line the oral and/or nasal cavities in 10 patients. Bilateral flaps were used in one patient suffering from lye ingestion and in one patient undergoing bilateral lip reconstruction. All reconstructions were performed in two stages separated by 3 to 4 weeks. In the first stage, an epithelial lining was created by placing a non-hair-bearing skin graft over the temporoparietal fascia. In the second stage, the fascial flaps were raised as vascular islands and transferred as either pedicled or free flaps. All flaps survived and improved function for the patients. This procedure may be useful in refined reconstructions of moderately sized intraoral and nasal defects.


The authors retrospectively reviewed all patients who had had buccinator myomucosal flap procedures at the Groote Schuur Hospital between 1999 and 2004. Patients were also recalled to assess flap sensation and to record reduction of mouth opening as a consequence of donor site scarring. Of 14 patients, there was one flap failure. Sensation was present in 71% of flaps, and there was no trismus from donor site scarring.


Total nasal defects present daunting reconstructive challenges. The nasal skeleton can be successfully fabricated with bone and cartilage. A forehead flap produces an excellent color match for nasal skin. The internal lining is the most difficult of the three layers to reconstruct. Local tissue is often unsatisfactory in amount and/or vascular supply. The authors presented results from one patient with a total nasal defect. They used a paramedian forehead flap to resurface the external defect. The nasal skeleton was reconstructed with split calvarium and conchal cartilage. A fascial flap harvested from the forearm replaced the intranasal lining. Turbinate grafts were placed to line the flap. Postoperative breathing was excellent.


The authors studied the vascular anatomy of the buccinator muscle in fresh cadavers. Based on results, two patterns of buccinator myomucosal island flaps supplied by buccal arterial branches were proposed. The buccal myomucosal neurovascular island flap (posteriorly based), supplied by the buccal artery, its posterior buccal branch, and the long buccal nerve, can be passed through a tunnel under the pterygomandibular ligament for closure of mucosal defects in the palate, pharyngeal sites, the alveolus, and the floor of the mouth. The buccal myomucosal reversed-flow arterial island flap (superiorly based), supplied by the distal portion of the facial artery through the anterior buccal branches, can be used to close mucosal defects in the anterior hard palate, alveolus, maxillary antrum, nasal floor and septum, lip, and orbit. The authors used the flaps in 12 patients. There was no flap necrosis, and all had satisfactory aesthetic and functional results.
The anterior thorax presents a reservoir of tissue available for head and neck reconstruction, thoracic reconstruction, and breast reconstruction. Before microsurgery, deltopectoral flaps and pectoralis flaps were the mainstay of reconstruction, and they remain important today. In thoracic applications, flaps in this area are incredibly helpful in solving difficult complications of intrathoracic procedures, including mediastinitis, bronchopleural fistulas, and empyema. Equally important, the anterior thorax presents the platform on which breast reconstruction is based.

- Deltopectoral Flap
- Pectoralis Minor Flap
- Lateral Intercostal Artery Perforator (LICAP) Flap
- Serratus Flap
- Pectoralis Major Flap
- Supraclavicular Artery Flap
ANATOMIC LANDMARKS

**Landmarks**

The flap is located in the upper portion of the anterior chest, from the sternum onto the deltoid muscle. Specific landmarks are the sternal edge, infraclavicular line, and deltopectoral groove.

**Size**

10 × 20 cm × 10 cm diameter.

**Composition**

Fasciocutaneous.

**Dominant Pedicles**

Perforating branches of the internal mammary system.

**Nerve Supply**

Anterior intercostal nerves.
Section 6A

ANTERIOR THORAX

Deltopectoral Flap

CLINICAL APPLICATIONS

Regional Use
- Middle and lower thirds of the face
- Neck
- Intraoral cavity

Distant Use
- Head and neck

Specialized Use
- Esophageal reconstruction
ANATOMY OF THE DELTOPECTORAL FLAP

Dominant pedicles: Perforating branches of internal mammary artery

Fig. 6A-1
Anterior Thorax

6A: Deltopectoral Flap

ANATOMY

Landmarks The deltopectoral flap is located in the upper portion of the anterior chest, from the sternum onto the deltoid muscle. Specific landmarks are the sternal edge, infraclavicular line, and deltopectoral groove.

Composition Fasciocutaneous.

Size 10 × 20 cm.

Arterial Anatomy

Dominant Pedicles  *First, second, and third perforating branches of the internal mammary artery*

The flap will survive on only one of these vessels. The second or third perforators are usually largest.

Regional Source Internal mammary artery.

Length 1 to 2 cm.

Diameter 1 to 2 mm.

Location Within 4 cm of the midsternal line.

Venous Anatomy

Single veins accompany the arterial perforators; the average venous diameter is 1 to 2 mm.

Nerve Supply

Sensory The second through the fourth intercostal nerves provide segmental sensory innervation.
**Vascular Anatomy of the Deltopectoral Flap**

**Fig. 6A-2**

**A and B:** Dominant pedicles: First, second, or third perforating branch of internal mammary artery (D)

**C:** Dominant pedicle: Third perforating branch of internal mammary artery (D₃)
FLAP HARVEST

Design and Markings

The flap is designed diagonally upward across the upper chest and shoulder. The base lies over the second, third, and fourth costal cartilages. The upper border follows the infraclavicular line to the deltopectoral groove. The lower border runs parallel to the upper border and usually lies a few centimeters above the undisplaced nipple. The distal extent of the standard flap is just beyond the deltopectoral groove. However, the flap can be safely extended to the tip of the shoulder and beyond with a vascular delay, although this must be accomplished in two surgical stages.

Patient Positioning

The patient is placed in the supine position for both flap harvest and inset. The ipsilateral arm should be adducted to prevent distortion of anatomic landmarks.
GUIDE TO FLAP DISSECTION

Incisions are made through the skin and subcutaneous tissues down to the underlying pectoralis or deltoid muscle. *The fascia overlying the muscles must be included with the flap.* Fasciocutaneous perforating vessels through the pectoralis muscle enter the flap medially on its deep surface within 4 cm of the midsternal line.

**Standard Flap**

Flap elevation proceeds from lateral to medial. The distal end is incised through skin and subcutaneous tissues down to and including the fascia over the deltoid muscle. The dissection then proceeds rapidly through a relatively bloodless plane across the deltoid, across the deltopectoral groove, and onto the pectoralis major. The axially oriented vessels can sometimes be seen within 6 cm of the midline just above the fascia. The dissection is continued until the perforators can be seen emerging through the pectoralis major muscle. Any cutaneous branches of the thoracoacromial vessels that are encountered are ligated below the clavicle as dissection proceeds proximally.

![Fig. 6A-4](image)

**Esophageal Reconstruction**

Deltoplectoral flaps are often used to provide skin coverage for underlying esophageal reconstruction using free vascularized jejunal flaps. The flap provides a large area of pliable thin skin through which a tracheal stoma can be passed to provide a stable tracheostomy site without the risk of soft tissue prolapse into the airway. For staged reconstruction of the esophagus with a tubed deltopectoral flap, the flap is tubed with the cutaneous surface inside to provide lining for the neoesophagus. The upper border of the tubed flap is approximated to the esophagus, and the lower border is kept open as a temporary controlled salivary fistula. At the second stage (usually 2 to 3 weeks later), the attached base of the deltopectoral flap is divided, the tubing is completed, and the distal esophageal anastomosis is completed. Alternatively, the tubed distal end of the flap can be inset into the esophagus as a complete tubed conduit attached on its cutaneous pedicle for blood supply. A nasogastric tube is placed through the construct before insetting the flap into the proximal and distal esophageal ends. Three weeks later, the cutaneous pedicle can be divided.
Prefabrication for Tracheal Reconstruction

A multistaged approach has been described in which rib cartilage or other engineered scaffold with palatal or buccal mucosa can be placed beneath the distal end of the flap at the time of vascular delay. Once this tissue has achieved an adequate blood supply at 3 to 4 weeks after surgery, the flap can be raised, and the attached and integrated chondromucosal elements can be spliced into the airway for tracheal reconstruction, using the remaining skin pedicle for external soft tissue cover. At a third procedure, the skin bridge can be resected as needed.

FLAP VARIANTS

• Delayed flap
• Second and/or third intercostal perforator (IMAP) flap, as pedicled or free flap

Delayed Flap

The delayed flap is outlined beyond the deltopectoral groove and onto the anterior border of the shoulder—almost to the tip. The superior and inferior incisions are made and the flap is undermined below the fascia. All perforating vessels other than the mammary perforators must be divided at this stage, including the branches of the thoracoacromial artery. The distal incision is left intact and allows blood supply to the tip. This will be divided in 7 to 10 days. Superiorly, the incision should be carried proximal enough to identify and ligate the cutaneous branches of the thoracoacromial vessels. This simple maneuver dramatically improves the delay effect. A Silastic sheet or a tissue expander may be placed beneath the area of the delayed flap, or the back of the flap may be skin grafted, with the graft extending onto the deltoid donor site. The flap may be transferred safely 7 to 10 days after division of the distal edge.

Fig. 6A-5  A, In stage one of the delay procedure, the superior and inferior incisions of the proposed delayed flap are made and the flap is completely undermined. The distal edge of the flap is not incised. B, In stage two, 7 to 10 days later, the distal edge is incised. The flap is now surviving only on the mammary perforators. Transfer of the flap may be done 7 to 10 days later.
Internal Mammary Artery Perforator Flap
Although rarely used for microvascular transplantation, the deltopectoral flap can be transferred on the second and/or third perforating branch from the internal mammary artery as a perforator flap (IMAP). The vascular pedicle is the IMA. The flap is elevated as described for the standard flap or the delayed flap, and dissection is continued from lateral to medial until the perforators are isolated. Next pectoral muscle and a small section of rib(s) are removed to allow harvest of the IMA intact with its perforators. The flap may then be used as a pedicle flap or be transferred as a free tissue transfer.

 ARC OF ROTATION

Standard Flap
The deltopectoral flap reaches the neck, lower face, oral cavity, and mediastinum. Flexion of the neck can improve the reach of the flap.

Fig. 6A-6 Once perforators to the skin paddle are identified, dissection follows the vessels through pectoralis major muscle, which is removed to show the underlying ribs. Removal of the intervening rib is required to include more than one perforator. Additional ribs are removed to lengthen the pedicle and improve the arc of rotation, or if longer vessels are needed for a free tissue transfer.
Delayed Flap
The delayed version of the deltopectoral flap has a longer reach and may be folded for intraoral reconstruction or for an extended arc of rotation to the midface or deep within the mediastinum.

**FLAP TRANSFER**
The flap is transferred to its recipient site by rotation or transposition. For local neck uses, such as parastomal defects, one-stage transfer is possible. For remote defects such as the face or neck, or when tunneling is not possible, the flap is often used as an external tubed pedicle flap and divided in stages at 3 weeks after transfer. The base and midportion of the flap can be easily tubed to avoid dessication during the delay period and to simplify dressing care. If tubing constricts the flap at all and causes ischemia or congestion, tubing should be avoided and the open part of the flap should be skin grafted or dressed with a synthetic dermal substitute. The staged transfer of a deltopectoral flap is rarely performed because of the wide array of free flaps available for facial reconstruction. For chest wall and mediastinal defects, the flap can be folded down onto the defect, and, once healed, the dog-ear at the base of the rotation point can be revised or resected and the flap inset appropriately.

**FLAP INSET**
A tension-free closure is the goal for a rotational or transposed flap. Any dog-ears at the rotation point should be revised secondarily. The second stage, dividing the tube and insetting the flap, is performed after the appropriate delay period. This can be tested with a tourniquet before division.

**DONOR SITE CLOSURE**
The donor site is rather obvious and almost always requires a skin graft for distal closure, although the proximal portion of the wound may be closed directly. In women, elevation of the breast can allow primary closure. Tubed pedicles can be returned to their original site and replace the proximal part of the skin graft.
CLINICAL APPLICATIONS

This 70-year-old man developed erosion of his esophageal stent into the back of the trachea below his tracheostomy site. An uncontrolled salivary fistula caused difficulty with breathing. Thoracic surgeons resected the area of erosion and replaced the stent. A deltopectoral flap that was previously delayed was placed between the esophagus and trachea to reinforce the repair and close the superior dead space created when he was converted to a mediastinal tracheostomy site. He went on to heal without requiring revision of the flap.

Fig. 6A-9  A, The thoracic surgeons resected the area of erosion and replaced the stent. B, A delayed deltopectoral flap was placed between the esophagus and trachea. (Case supplied by G.J.)

This 65-year-old man with a squamous cell carcinoma of the head and neck had a stomal recurrence of the tumor that required wide excision of the stoma and resection of previously irradiated skin, leaving a skin resurfacing requirement. This was an ideal case for a primary deltopectoral flap.

Fig. 6A-10  A, The preoperative defect is seen, with the shortened tracheal stump and neck skin defect. B, After a one-stage deltopectoral flap reconstruction and skin grafting of the donor site. The flap easily reached the lower neck and allowed tension-free closure around the deeper tracheal stoma. (Case supplied by MRZ.)
This 25-year-old man was shot in the cheek, which resulted in a full-thickness defect of the cheek and segmental mandibular loss. Initial lifesaving care included ligation of the carotid artery to prevent exsanguination and suturing of the tongue to the cheek defect to control the wound. Once the patient was stable, a reconstruction was planned: first, soft tissue reconstruction with a deltopectoral flap, to be followed later with a mandible reconstruction with a free fibular flap anastomosed to the contralateral neck.

Fig. 6A-11  A, Preoperative view 2 weeks after the patient’s initial injury. The full-thickness defect of the cheek is seen, but the tongue sutured to the cheek obscures the deficiency in the floor of the mouth. B, The planned deltopectoral flap, delayed as described above. C, The tongue was released and the deltopectoral flap inset into the floor of the mouth, allowing normal tongue mobility. The donor site was skin grafted. D, The deltopectoral flap was then folded and used to line the inner cheek and was sutured to the outside of the cheek, closing and relining the defect. The flap was tubed for wound control of the exposed pedicle, and a bolster was placed over the skin graft. E, Two weeks postoperatively, the pedicle was divided and returned to the chest to replace some of the skin graft. There was lining for the cheek, inside and out. F, After free fibular mandible reconstruction, two serial excisions of the skin paddle were performed, and the external skin paddle was completely removed, leaving the internal cheek and floor of the mouth lining and a more aesthetic appearance. (Case supplied by MRZ.)
This 52-year-old woman had squamous cell carcinoma and underwent resection of her right cheek and mandibular body. The defect was reconstructed with a free osteocutaneous fibula flap, which failed. A pectoralis muscle flap and skin graft was performed as a salvage procedure. She subsequently presented with a neck contracture and band. Because the pectoralis muscle had been raised on the thoracoacromial system and the internal mammary perforators were intentionally left in situ, a deltopectoral flap was still possible and was transferred to resurface the neck and relieve contracture.

Fig. 6A-12  A, The patient presented 9 months after her pectoralis major muscle salvage procedure. Her plate was stable, and there was no intraoral exposure. She was bothered by the bandlike neck contracture from her reconstruction. B, Debridement of the pectoralis muscle and skin graft superiorly released the contracture, but a skin defect remained. The previous skin graft caused contracture, so a deltopectoral skin flap was chosen to resurface the area. A standard deltopectoral flap would not reach the wound without tension, so a delay procedure was planned. C, The standard deltopectoral flap was outlined. Lines were incised, and the flap was completely undermined except in the area of the mammary perforators. A second delay was performed, extending the incisions above and below and undermining the distal flap. D, The distal end of the flap was divided under local anesthesia in the office 1 week later. The patient is shown 1 week after the final distal delay, ready for flap transfer.
Fig. 6A-12  **E,** The flap was elevated. Note the length that was attained, with excellent vascularity if delayed correctly. **F,** The flap was rotated to the cheek. The arc of rotation could be extended by backcutting the flap, sacrificing one of the distal internal mammary artery perforators. **G,** The flap was tubed and inset. The large donor site required a skin graft. **H,** Four months after the division and inset, the contracture band is resolved and the patient has improved neck mobility. She is a candidate for further aesthetic revisions. (Case supplied by MRZ.)
This 69-year-old man required a laryngopharyngectomy for squamous cell carcinoma of the larynx. He underwent a cervical esophageal reconstruction with a free jejunal flap. As is often the case, the patient had previously had irradiation of his neck, and after the resection and flap reconstruction, a large skin defect remained. Rather that select another free flap, a deltopectoral flap was an easy solution for resurfacing at the end of an already long case.

Fig. 6A-13  
A, The skin defect is seen after laryngopharyngectomy and free jejunal cervical esophageal reconstruction. The proposed deltopectoral flap is outlined.  
B, The neck defect was resurfaced with the deltopectoral flap and the donor site was partially closed. The remainder was skin grafted.  
C, At 6-month follow-up, the flap remains well healed over the functional jejunal reconstruction, and the skin grafted donor site is acceptable to the patient. (Case supplied by MRZ.)
This 58-year-old man had T4 squamous cell carcinoma of the floor of the mouth; this was resected. Surgery included mandibular resection, and his surgical defect was reconstructed with a fibula osteocutaneous flap. He had bilateral neck dissections, followed by a course of radiation. Subsequently he had breakdown of the skin of his neck, which was treated with skin grafts. This resulted in unstable skin in his neck, characterized by recurrent breakdown. The plate fixing his fibula intraorally was exposed, so he needed resuspension of his lip. However, the tightness of the tissues in his neck, in addition to causing this problem, was preventing its resolution. Clinically, the neck felt stiff and hard. He required resurfacing but was not a good candidate for free tissue transfer because of the condition of the soft tissues of his neck and the anticipated difficulty in dissecting recipient vessels for a free flap.

Fig. 6A-14  A, The patient is seen before resurfacing. B, This was achieved with bilateral obliquely oriented IMAP transposition flaps. C, These were pedicled using the second IMAP, without the need for mobilization of the internal mammary artery. D, Stable closure was achieved, as well as direct closure of the secondary defect. (Case courtesy Peter C. Neligan, MD.)
This 62-year-old man had carcinoma of the pharyngoesophagus. His resection included a partial pharyngectomy as well as a laryngectomy. The posterior half of the pharyngeal mucosa was preserved, so that he needed reconstruction with an anterior patch to reconstruct his esophagus. Surgical margins were clear. A postoperative course of radiation was planned. The patient had peripheral vascular disease and was not an ideal candidate for free tissue transfer because of comorbidities: in addition to his peripheral vascular disease, he was also diabetic, hypertensive, and had a history of previous myocardial infarction.

**Fig. 6A-15**  
A, Design of the IMAP flap. B, Three perforators were harvested with this flap, necessitating the removal of the two intervening costal cartilages to mobilize the internal mammary artery and lengthen the pedicle. C, The flap was pedicled to the neck and inset as a patch onto the esophagus. D, Direct closure of the donor site was achieved. (Case courtesy Peter C. Neligan, MD.)
Pearls and Pitfalls

- When transposing the flap to the head and neck, skeletonization of the perforating vessels should be avoided.
- A preliminary delay is necessary for flaps extending beyond the deltopectoral groove. Delay should be accompanied by division of the cutaneous branches of the thoracoacromial vessels as well as elevation of the distal end of the flap.
- The donor site in women distorts the ipsilateral breast, but primary closure is possible in select cases.
- As a free flap, the sacrifice of ribs and the IMA is necessary but is well tolerated by patients.
- The supraclavicular flap has largely supplanted the deltopectoral flap as a regional flap for head and neck defects, because it has a more favorable point of rotation, is easier to close primarily, and largely captures the area over the deltoid (see Section 6F).

EXPERT COMMENTARY

Peter C. Neligan

The deltopectoral was a workhorse flap in head and neck reconstruction in the 1960s and 1970s, before flaps such as the pectoralis major and others were described. The deltopectoral flap has now largely fallen into disuse as traditionally described because of our better understanding of the vascular anatomy of the region and of this flap. In his original description, Bakamjian described the blood supply of this flap as coming from the first four perforating vessels from the internal mammary artery. At that time, the term perforator was not used, and of course, the concept of perforator flaps as we know them today was not yet conceived.

Advantages and Limitations

The main advantage of this flap is its proximity to the neck and the fact that the skin of the upper thorax is usually relatively thin and pliable. Another advantage is that it can be raised very quickly.

However, there are many disadvantages. The first is that the flap needs to be delayed if the skin overlying the deltoid is required, and in almost all situations, it is needed to reach the lower face. This significantly limits its usefulness. The donor site is also a major problem, because it invariably needs to be grafted, leaving a very unsightly scar in the upper thorax and shoulder. Furthermore, revisionary surgery is often required, particularly if the flap has been tubed. But even if it has not been tubed, there is often a dog-ear at the pivot point that requires revision secondarily. However, although the original design of the flap precluded correction of the dog-ear at the time of rotation, with improved understanding of the vascular anatomy, we know that this is not necessarily the case.

Anatomic Considerations

As I have already indicated, we now know more about the anatomy of the internal mammary artery and its perforators than Bakamjian did when he first described the flap. We also know that it is perfectly safe to skeletonize perforators, and we know more about the relative contributions of the first four internal mammary perforators to the perfusion of the deltoid. Continued
of the skin of the anterior chest. So, for example, we now know that in most cases, the second internal mammary perforator (IMAP) is dominant. Furthermore, the length of the pedicle can be significantly increased by removing costal cartilage and mobilizing the internal mammary vessels. This yields a pedicle length of up to 8 or 9 cm, which is more than enough to reach the neck, greatly increasing the arc of rotation. We also know that in general, one perforator can perfuse its own territory as well as the adjacent one. What that means is that we can usually harvest the amount of tissue we need based on just one perforator. Also, there is more flexibility in the axiality of the flap than Bakamjian realized. This allows us to design the flap in different ways—vertically, obliquely, or horizontally.

**Personal Experience and Insights**

I haven’t done a deltopectoral flap since the 1980s, because I have found the pectoralis major flap to be more useful, and using it avoids the necessity for skin grafting the donor site. More recently, I have converted to the IMAP flap, since this avoids the necessity of harvesting the pectoralis muscle while still allowing me to close the donor defect directly.

**Recommendations**

**Planning**

The only time I plan a deltopectoral flap is when I am harvesting a pedicled pectoralis major flap for head and neck reconstruction. In that case, I like to preserve the traditional deltopectoral territory in case something happens and I might need it. If I did need it, I would harvest it as an IMAP flap.

**Technique**

I mentioned that harvest of the traditional deltopectoral flap is quick. The pedicle is medial, so most of the dissection can be done suprafascially with cautery. In fact, in the traditional deltopectoral flap, one doesn’t necessarily even need to see the pedicles. If I am harvesting an IMAP flap, this is also quick. The dissection can be done up to the pedicle with cautery, and once the pedicle is identified, it can be dissected with scissors in the standard manner of perforator dissection. If extra length is required, the internal mammary artery is exposed and mobilized.

Preoperative CT angiography can identify the dominant pedicle, or this decision can be made with the use of indocyanine green angiography. If neither of these options is available, an exploratory incision can be made medial to the perforators, allowing direct visualization to determine which is the biggest perforator. Alternatively, the flap can be mobilized on multiple perforators; this requires that the costal cartilage between these perforators be removed so that the internal mammary can be mobilized.
Complications: Avoidance and Treatment

If the flap is being used as a traditional deltopectoral flap, it is important to decide whether the dimensions of the flap demand delay. If the flap extends beyond the deltopectoral groove, delay will be necessary. It is also important to avoid tension.

In the chapter it is mentioned that flexion of the neck may help with tension-free closure. This is a maneuver that makes acceptance of the flap very difficult for the patient and increases the risk of tip necrosis of the flap.

Take-Away Messages

The principal take-away message is that this flap is, by and large, obsolete. There are many better flaps available. If this skin territory is to be used as a flap, it is much better used as an IMAP flap.

References


Bibliography With Key Annotations

Clinical Series


This is the original description of the deltopectoral flap. The flap was used as a tube for reconstruction of the cervical esophagus in a two-stage procedure. The results were successful in 9 of 10 cases.


Four cases were presented to illustrate the evolution of the deltopectoral flap in Dr. Bakamjian’s unit. The delay procedure and prefabrication of the tube for esophageal reconstruction were demonstrated.


Further refinements and extensions of the application of this flap for reconstruction in the head and neck were described.


The authors highlighted the resurgent importance of this flap for postburn head and neck reconstruction. They reported on five cases of head and neck reconstruction using the deltopectoral flap: one peroral reconstruction after ballistic trauma, one nasal reconstruction after burn, and three cases of neck reconstruction after burn contractures. Technical simplicity and reliability are the main features of this flap. They emphasized the thin, pliable skin quality and the ability to extend the surface of the skin paddle with a flap delay. Previous tissue expansion can minimize donor site morbidity. The flap division necessitates a second surgical procedure.
Feng GM, Cigna E, Lai HK, et al. Deltopectoral flap revisited: role of the extended flap in reconstruction of the head and neck. Scand J Plast Reconstr Surg Hand Surg 40:275, 2006. This paper revisited the utility of the deltopectoral flap in a 34-case series of head and neck reconstruction performed between 1987 and 2004. Twenty-nine had one or more failed attempts at microsurgical reconstruction after excision of cancer. Five were treated primarily. The flap was divided at least 3 weeks after the primary operation. All 34 flaps survived, and there were no donor site complications. Twenty-seven patients had an uncomplicated outcome, but the remaining seven required later closure or skin grafting, usually with a local anesthetic, for complications. They commented on the value of this flap as a backup procedure for microsurgeons treating large head and neck defects.

Guerrissi JO. Lateral deltopectoral flap: a new and extended flap. J Craniofac Surg 20:885, 2009. Tissues of the pectoral area such as skin and pectoralis major muscle are used in safe and extended flaps for cervical and neck reconstructions. As blood supply is derived from medial vessels (internal mammary artery) or lateral (thoracodorsal and lateral thoracic arteries), two different flaps can be constructed: medial and lateral deltopectoral. The medial deltopectoral flap was developed by Bakamjian as an axial-pattern skin flap, and its blood supply depends on perforating branches from the internal mammary artery. When either parasternal skin or pectoralis major muscle must be resected, this flap obviously cannot be used. In this article, the author described a new lateral deltopectoral flap based on lateral pedicles (from the axilla and lateral thoracic area). The successful use of this lateral deltopectoral flap in an extended cervical and thoracic reconstruction after resection of a giant basal cell carcinoma demonstrates that it must be considered as an alternative technique.

McCarthy CM, Kraus DH, Cordeiro PG. Tracheostomal and cervical esophageal reconstruction with combined deltopectoral flap and microvascular free jejunal transfer after central neck exenteration. Plast Reconstr Surg115:1304; discussion 1311, 2005. Combined defects of the skin, larynx, pharynx, and esophagus after central compartment exenteration of the neck can be extremely difficult to reconstruct. The authors evaluated the reconstruction of the central compartment using a combination of free jejunal transfer for pharyngoesophageal reconstruction, together with regional deltopectoral flaps for tracheostomal reconstruction and cutaneous resurfacing. Myocutaneous flaps such as the pectoralis major and latissimus dorsi have been used previously for external coverage but can be bulky, causing obstruction of the tracheostoma. Seven patients were reconstructed with seven jejunal and nine deltopectoral flaps. Five patients required resection for massive pharyngocutaneous fistulas. Mean age was 68.7 years and mean follow-up was 1.9 years. Overall free jejunal and deltopectoral flap survival was 100%, with no partial loss. All patients maintained an adequate airway with stomal patency. The authors concluded that complicated defects can be effectively repaired with free jejunal transfers to restore continuity of the alimentary tract and deltopectoral flaps to reconstruct the tracheostoma and surrounding cutaneous defects. They emphasized the large volume of well-vascularized, thin, pliable tissue which allows suturing of the tracheal remnants to skin edges without tension, avoiding intraluminal prolapse of excess soft tissues.

Mendelson BC, Woods JE, Masson JK. Experience with the deltopectoral flap. Plast Reconstr Surg 59:360, 1977. The authors presented an extensive review of 63 deltopectoral flaps. Six flaps were used for hand coverage and the remainder for head and neck reconstruction, including skin cover; lining of the oral cavity, pharyngeal wall, or tubed for esophageal reconstruction; and full-thickness defects of the oral cavity and pharyngeal wall. Forty percent of the patients had complications: 9.5% had major complications and the remainder were described as minor complications. Recommendations to minimize complications included flap design and technical aspects of flap transfer.

**Flap Modifications**

Harii K, Ohmori K, Ohmori S. Successful clinical transfer of ten free flaps by microvascular anastomoses. Plast Reconstr Surg 53:259, 1974. Microvascular transplantation of the deltopectoral flap was described. This article is of historical interest in that it presented the first successful microvascular transfer of multiple tissues, including the groin flap, myocutaneous flaps, and scalp transfers.

The authors presented various modifications of the flap, including a vertical split, a tangential split, and deepithelialization of portions of the flap for tunneling. The tangential split allows the “carrying” portion of the flap to be buried permanently beneath the skin of the neck, thus obviating a second procedure for division of the pedicle following definitive flap inset. The vertically split flap will allow simultaneous coverage of both lining and external surface defects.


The authors proposed extending the role of the flap in reconstructive surgery of the head and neck, with the arc of rotation to include the posterior triangular mastoid, ear, parotid, cheek, angle of mouth, and chin. The use of the flap for coverage of the hand as a tubed pedicle flap was also presented.


The authors presented a new surgical procedure using a deltopectoral flap combined with a costal cartilage graft and mucosal graft for tracheal reconstruction. In one case, a tracheostenosis was reconstructed with a deltopectoral flap combined with a costal cartilage graft. In the other case, a tracheal defect was reconstructed with a deltopectoral flap combined with a costal cartilage graft and a palatal mucosal graft. Although the operation is a multistage procedure, the technique provides a satisfactory clinical solution for a potentially devastating clinical complication.


The skin overlying the territory of the deltopectoral flap is elevated at the dermal level based on the superior transverse edge of the standard deltopectoral flap. Subsequently, the underlying deltopectoral flap is elevated as a turnover flap for coverage of contralateral chest wall radionecrotic wounds. Skin-graft coverage is required for the exposed deep surface of the deltopectoral flap, whereas the preserved skin flap based on the superior clavicular edge of the deltopectoral flap is returned to the donor site. The inferior portion of the radiation defect of the chest wall was covered with a latissimus dorsi myocutaneous flap. This technique was successful in three patients with postmastectomy radiation defects measuring 20 by 20 cm.

Complications


Three major immediate complications of the flap were discussed: necrosis, infection, and separation. Seven cases of partial flap necrosis were described, and etiologic factors, including a narrow base, excessive length, and kinking of the pedicle, were identified. Infection occurred in three cases, resulting in flap loss. One case of flap separation occurred. Recommendations were made for minimizing the risk of complications with the use of this flap.


The use of 57 deltopectoral flaps in 53 patients was reviewed. No complications were observed in 37 of the 57 flaps. Of the remaining 20 flaps, 6 had major complications and 14 had minor complications. Major complications included total flap loss in one patient and sufficient partial loss in five other patients to require alternate flaps. Etiologic factors were discussed, and recommendations for minimizing complications were made. The authors concluded that this is a safe and reliable flap.
ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>A thin, triangular muscle on the anterior chest wall deep to the pectoralis major.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>$15 \times 8$ cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>Third, fourth, and fifth ribs near the costochondral junction.</td>
</tr>
<tr>
<td>Insertion</td>
<td>Coracoid process of the scapula.</td>
</tr>
<tr>
<td>Function</td>
<td>Stabilization of the scapula and protraction of the scapula and shoulder.</td>
</tr>
<tr>
<td>Composition</td>
<td>Muscle.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type III.</td>
</tr>
<tr>
<td>Dominant Pedicles</td>
<td>Branches of the thoracoacromial and lateral thoracic vessels, both of which are derivatives of the axillary artery.</td>
</tr>
<tr>
<td>Minor Pedicle</td>
<td>Direct branch of axillary artery to pectoralis minor.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td><em>Motor:</em> The pectoralis minor is innervated by the medial and lateral pectoral nerves. The lower two digitations of the muscle are innervated by the medial pectoral nerve, and the uppermost digitation is innervated by a branch of the lateral pectoral nerve.</td>
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Section 6B

ANTERIOR THORAX

Pectoralis Minor Flap

CLINICAL APPLICATIONS

Regional Use
- Axilla
- Shoulder
- Breast

Distant Use
- Head and neck
- Forearm and hand
- Lower extremity

Specialized Use
- Facial reanimation
ANATOMY OF THE PECTORALIS MINOR FLAP

Origin and insertion of pectoralis minor

Vascular supply

Nerve supply

Fig. 6B-1

Dominant pedicles: Pectoral branch of thoracoacromial artery; branch of lateral thoracic artery
ANATOMY

Landmarks A thin, triangular muscle on the anterior chest wall deep to the pectoralis major.
Composition Muscle.
Size $15 \times 8$ cm.
Origin Third, fourth, and fifth ribs near the costochondral junction.
Insertion The fibers converge on the coracoid process of the scapula.
Function Stabilization of the scapula and protraction of the scapula and shoulder.

Arterial Anatomy (Type III)

Dominant Pedicle **Pectoral branch of thoracoacromial artery**
REGIONAL SOURCE Axillary artery.
LENGTH 8 to 10 cm.
DIAMETER 2 mm.
LOCATION The branch from the thoracoacromial vessel passes down on the deep aspect on the pectoralis major with the lateral pectoral nerve from beneath the middle third of the clavicle to enter pectoralis minor on its deep surface proximally.

Dominant Pedicle **Lateral thoracic artery**
REGIONAL SOURCE Lateral thoracic artery.
LENGTH 8 to 10 cm.
DIAMETER 1.5 mm.
LOCATION The lateral thoracic artery runs down the anterolateral chest wall and enters the pectoralis minor at its lateral border, supplying the muscle distally.

Minor Pedicle **Direct branch of the axillary artery to pectoralis minor**
REGIONAL SOURCE Axillary artery.
LENGTH 4 to 5 cm.
DIAMETER 0.5 to 1 mm.
LOCATION On the deep surface of the muscle, close to its insertion, located centrally behind the muscle. This minor pedicle lies halfway between the two dominant pedicles.

Venous Anatomy

Single veins accompanying the arterial circulation; average venous diameter is 1.5 to 3 mm.

Nerve Supply

Motor The pectoralis minor is innervated by the medial and lateral pectoral nerves. (Medial and lateral refer to cords of the brachial plexus, not anatomic position within the muscle.) The lower two digitations of the muscle are innervated by the medial pectoral nerve, and the uppermost digitation is innervated by a branch of the lateral pectoral nerve.
**VASCULAR ANATOMY OF THE PECTORALIS MINOR FLAP**

**Fig. 6B-2**

**Dominant pedicles:** Pectoral branch of thoracoacromial artery ($D_1$); branch of lateral thoracic artery ($D_2$)

**Minor pedicle:** Branch of axillary artery ($m$)

axa, Branch from axillary artery; lta, lateral thoracic artery; taa, thoracoacromial artery

Elevation of flap after release of origin
Anterior Thorax  •  6B: Pectoralis Minor Flap

Deep surface of flap

Radiographic view

Fig. 6B-2

Dominant pedicles: Pectoral branch of thoracoacromial artery (D1); branch of lateral thoracic artery (D2)
FLAP HARVEST

Design and Markings

The patient is marked in the erect position with the arm at the side. The clavicle and outline of pectoralis major are marked emphasizing the position of the inferolateral border of pectoralis major. The coracoid process is marked and the potential position of pectoralis minor is drawn within the confines of the pectoralis major outline. The third, fourth, and fifth ribs are marked anteriorly.

Patient Positioning

The patient is placed in the supine position for both flap harvest and inset.
GUIDE TO FLAP DISSECTION

The flap is exposed through an anterolateral chest wall incision, exposing the lateral border of pectoralis major muscle. The pectoralis major is retracted to expose the underlying pectoralis minor muscle.

![Diagram A](image1)

**Fig. 6B-4 A,** Exposure of the pectoralis minor muscle.

The lateral thoracic vessels are also identified along the lateral border of the pectoralis major muscle lying over the serratus anterior muscle. The lateral thoracic vessels are then traced under loupe magnification to the undersurface of the pectoralis minor muscle.

![Diagram B](image2)

**Fig. 6B-4 B,** Exposure of the lateral thoracic pedicle lying lateral to the pectoralis major on the serratus and entering the pectoralis minor's deep surface.
The insertion of the pectoralis minor into the coracoid process is divided and the muscle retracted downward. This should expose the entire vascular and motor nerve supply of the pectoralis minor.

The thoracoacromial trunk and its pectoral branch to the pectoralis minor are identified. If there is a minor pedicle, a direct branch of the axillary artery, it also is identified. The two or three vessels are then evaluated and a decision is made to base the flap on the largest vessel. The veins will follow the arteries and are dissected along with the artery. The other two vessels are then divided. The lateral and medial pectoral nerves are identified, and the branches to each of the three digitations of the pectoralis major isolated and dissected free. The nerves are then traced proximally—the lateral pectoral nerve to the lateral cord of the brachial plexus and the medial pectoral nerve to the medial cord of the brachial plexus. The origin of the muscle from the third to the fifth ribs is then divided and the flap is prepared for microvascular transplantation. Pedicle dissection can be carried to the source vessel for additional length.

**Fig. 6B-4** C, Division of the pectoralis minor insertion to the coracoid.

The thoracoacromial trunk and its pectoral branch to the pectoralis minor are identified. If there is a minor pedicle, a direct branch of the axillary artery, it also is identified. The two or three vessels are then evaluated and a decision is made to base the flap on the largest vessel. The veins will follow the arteries and are dissected along with the artery. The other two vessels are then divided. The lateral and medial pectoral nerves are identified, and the branches to each of the three digitations of the pectoralis major isolated and dissected free. The nerves are then traced proximally—the lateral pectoral nerve to the lateral cord of the brachial plexus and the medial pectoral nerve to the medial cord of the brachial plexus. The origin of the muscle from the third to the fifth ribs is then divided and the flap is prepared for microvascular transplantation. Pedicle dissection can be carried to the source vessel for additional length.

**Fig. 6B-4** D, Pectoralis minor muscle divided from the origin and insertion, attached to only vessels and nerves.
FLAP VARIANTS

- Free microvascular flap
- Pedicled flap

**Free Microvascular Flap**
The pectoralis minor flap has become useful primarily for facial reanimation. Its value lies in its thin profile and broad belly, allowing it to be split around the oral commissure. The pedicle is reliable and of a workable diameter and length for facial reanastomosis.

**Pedicled Flap**
The value of the pedicled flap in breast reconstruction has dwindled now that acellular dermal matrices have become the material of choice for lower pole implant coverage. The muscle can be used to augment muscle bulk for intrapleural applications, but these situations are few and far between. Its arc of rotation onto the anterior shoulder makes it helpful for the coverage of small shoulder wounds.

**ARC OF ROTATION**
Because of its short pedicle length, the arc of rotation in a pedicled flap is limited to the anterior shoulder and clavicle. The flap has little value in breast or intrathoracic reconstruction.
FLAP TRANSFER
The flap is transferred to its recipient site based on the location of the defect.

FLAP INSET
When performing this flap for facial animation, particular attention has to be paid to appropriate tensioning of the flap to achieve adequate animation. The coracoid insertion of the muscle is sutured to the zygomatic fascia, and the terminal leaflets from the origin of the muscle are split around the oral commissure and nasolabial fold and are tensioned appropriately to achieve sufficient pull on these structures to create smile. The muscle should be sutured into the dermis of the nasolabial fold to achieve this goal. Microvascular anastomosis is performed to the facial artery over the body of the mandible, and nerve anastomosis is performed to the appropriate recipient motor nerve graft.

DONOR SITE CLOSURE
A simple linear closure of the lateral chest wall skin is done over a muscle placed between the pectoralis major muscle and the ribs at the site of the pectoralis minor donor site.

CLINICAL APPLICATIONS
This 29-year-old woman presented with facial paralysis 2 years after removal of an acoustic neuroma. Facial reanimation was planned with a two-stage free functional muscle transfer of the pectoralis minor.

Fig. 6B-6  A, The patient is seen preoperatively. B, Results are seen 18 months postoperatively, with good symmetry when smiling and good depressor function from the three-slip inset. (Case courtesy Adriaan O. Grobbelaar, MD.)
This 38-year-old man had developed Bell’s palsy 3 years previously; his recovery was minimal. Facial reanimation was planned with a two-stage functional muscle transfer of the pectoralis minor.

This patient had complete congenital facial paralysis. At age 18, she underwent functional muscle transfer using the pectoralis minor muscle.

**Fig. 6B-7**  
A, The patient is seen preoperatively. B, Results of the pectoralis minor transfer are seen 2 years postoperatively. Note the slight excess bulk in the cheek of the transferred muscle. (Case courtesy Adriaan O. Grobbelaar, MD.)

**Fig. 6B-8**  
A, The patient is seen preoperatively. B, Twenty years later, she has good symmetry, with excellent elevation of the upper lip but a slightly excessive depressor function on the nonparalyzed side. The muscle function did not deteriorate over time. (Case courtesy Adriaan O. Grobbelaar, MD.)
Pearls and Pitfalls

- When this flap is harvested for microvascular transfer, care should be taken to prevent injury to the axillary-subclavian vessels and the medial cord of the brachial plexus.
- When transplanting the muscle as a free flap for reanimation, the surgeon must pay particular attention to achieving the correct tension in the face to provide adequate correction of the smile.

EXPERT COMMENTARY
Adriaan O. Grobbelaar

Indications
The main indication for use of the pectoralis minor muscle flap is facial reanimation, although it has been used for anterior shoulder reconstruction as well as implant coverage in immediate breast reconstruction.

Advantages and Limitations
I prefer the pectoralis minor for facial reanimation because of its size; it does not need much reduction. Its fanlike shape and good tendinous insertion are ideal for facilitating perioral insertion. The muscle has been primarily employed because its function is relatively unimportant, and its removal causes minimal donor site problems. The muscle is approached through a curved incision in the axilla, and the scar does not seem to cause concern to patients (Fig. 6B-9).

The main limitation associated with the pectoralis minor flap is its pedicle length. It has to be used in conjunction with a cross-facial nerve graft and is not suitable for cases in which a longer pedicle will be required. Contraindications for use of this muscle include the following:

- Congenital absence of the muscle
- Donor vessel access in the neck because facial vessels are not available (such as when there has been previous surgery in the face)
- Need for one-stage surgery
Bilateral facial paralysis in which a branch of the fifth cranial nerve to the masseteric muscle will be used as the donor nerve and a long nerve pedicle will be required.

**Patient choice**

**Anatomic Considerations**

We documented the anatomy of the pectoralis minor in 97 consecutive cases. The dominant blood supply to the muscle was from a single artery in 77% of cases and took the form of an artery arising directly from the axillary vessel in 72% of cases. This pattern is supported by two cadaveric studies of the pectoralis minor arterial tree. That places the muscle in the Mathes and Nahai type II category (see Chapter 2), though it was not formally described in the original article. The venous drainage of the muscle primarily involves a single vessel draining directly into the axillary vein. The innervating roots are C6 through C8, with the traditional description of two nerves, the medial and lateral pectoral nerves wrapping themselves around the axillary artery and innervating the muscle from its dorsal surface. However, recent descriptions of the nervous anatomy are more complex.

**Personal Experience and Insights**

We have used the muscle in more than 528 cases of unilateral facial reanimation. It has always been used in conjunction with a cross-facial nerve graft in a two-stage procedure.

**Recommendations**

**Planning**

The patient is draped in the supine position. A two-team approach can shorten the operating time to approximately 4 hours if the contralateral side of the trunk is used and the flaps harvested at the same time as the facial dissection. Free draping of the arm on that side facilitates access to the flap.

**Technique**

The lateral edge of the muscle is identified and followed to the coracoid process of the scapula (Fig. 6B–10). Careful dissection around the tendinous insertion enables division of the tendon.

**Fig. 6B-10** The lateral edge of the pectoralis minor exposed.
The muscle is then retracted toward the origin with the help of a single 3-0 silk suture through the tendon (Fig. 6B-11). The vascular pedicle is identified, isolated, and divided. The axillary incision is closed over a suction drain.

![Fig. 6B-11 Retraction of the tendon from the coracoid process.](image)

The pectoralis minor muscle is split into three slips, and the tendinous insertion is anchored into the alar base and upper and lower lip (Fig. 6B-12). The upper fibers of the muscle are arranged well forward on the zygoma to emulate the zygomaticus muscle and elevate the upper lip.

![Fig. 6B-12 Three slips for insertion into the alar base, upper lip, and lower lip.](image)

The muscle is positioned in the face with the pedicle facing anteriorly for ease of microsurgical anastomosis (Fig. 6B-13). The facial vessels are used as recipient vessels and are prepared well up into the face to permit easy transposition.

![Fig. 6B-13 Inset with pedicle facing anteriorly to facilitate easy microsurgical anastomosis.](image)
Postoperative Care
We use a compression dressing over the operated side of the face. All blood-thinning medications are avoided.

Complications
Hematomas in the immediate postoperative period should be promptly evacuated, because they can compress the vascular pedicle and interfere with the blood supply, or they may be a symptom of venous flow problems, with blood leaking from the cut muscle edges. Meticulous hemostasis during the entire procedure is a very high priority. The incidence of hematomas in our series was 5.3%. Debulking of the muscle was required in 9.7% of cases. If the muscle is to be thinned at a later stage, it can be raised with the skin and the posterior part of the muscle reduced.

Take-Away Message
The anatomic variation of the pedicle and small vascular structures of the pectoralis minor flap require an experienced microsurgeon.

References
Bibliography With Key Annotations


Because there were conflicting data in the literature concerning the vascularization of the pectoralis minor, the authors conducted an anatomic study on cadavers preliminary to clinical application of a pedicle flap for clavicular coverage in three patients. Twenty flaps were dissected, yielding numerous anatomic variations. In all cases, the principal arteries penetrated the muscle in its upper part, either posteriorly or posterolaterally. This anatomic study justified the use of the pectoralis minor as a pedicle flap, with turnover just below the coracoid process. Accordingly, the three cases of clavicular defects were treated successfully. Reports in the literature propose an adipofascial turnover flap or a pectoralis major flap for clavicular coverage. The pectoralis minor pedicle flap is easy to dissect and reproducible, involving minor aesthetic sequelae and no functional complications. This flap, which has never been described in this application, would appear to be suitable for first-line treatment in this indication.


Following extensive tumor resection in the head-neck area, options for immediate defect reconstruction are needed to reduce healing time and improve rehabilitation. Reconstruction of significant areas of mucosal defects is best accomplished by introduction of a pliable regional transplant. The platysma myocutaneous flap has been used for defect reconstruction in the head and neck for more than 20 years; however, its popularity is limited. The authors reported on 25 patients who underwent surgical reconstruction with the platysma mucocutaneous flap for tumors of the oropharynx, hypopharynx, or oral cavity. The platysma flap is easy to harvest and has a generally low risk level. Complications are usually minor and may be avoided by precise preoperative planning. Necrosis of the skin-muscle flap occurred only after resection of the external carotid artery in two patients for whom a revision was necessary (stenting of the pharynx or secondary reconstruction by pectoralis major flap). Resection of the facial artery (three cases) did not lead to serious complications. Special attention must be given to the ipsilateral vascular supply and the length of the muscular pedicle. It is a cost-effective procedure, requiring less operative time.


The author reported a 25-year experience in the treatment of unilateral and bilateral facial palsies. The advent of cross-facial nerve grafts and revascularized muscle grafts gives a high proportion of facial reanimation. The choice for the muscle graft is the pectoralis minor. The latissimus dorsi can be used in unfavorable circumstances or in bilateral facial palsies. Although recovery of movement is high, the search for refinement and symmetry continues. This article encapsulated the author’s philosophy in trying to achieve these goals.


The pectoralis minor muscle has been used as an innervated, vascularized, free muscle graft for facial reanimation for 20 years. Throughout this period, several centers have demonstrated consistent success with functional muscle transfer; however, opinions have varied regarding the arterial pedicle of the flap. The lateral thoracic and thoracoacromial arteries have been proposed as the predominant arterial sources. The authors stated that they had found that a vessel (not described in anatomy textbooks) arising directly from the axillary artery and entering the muscle from its dorsal surface provides the dominant supply to the flap and is capable of sustaining it for free tissue transfer. The vascular pedicle encountered was recorded and photographed in 97 consecutive cases in which the pectoralis minor muscle flap was
The findings demonstrated that the dominant supply to the muscle was from a single artery in 77% of cases and took the form of an artery arising directly from the axillary vessel in 72% of cases. More than one major arterial source was noted in the remainder of their cases. The venous outflow was usually through single or multiple veins running directly from the muscle into the axillary vein.


Breast cancer treatment has undergone a major change with breast conservation surgery (consisting of lumpectomy and axillary dissection or sentinel lymph node biopsy), which now forms a major proportion of the total number of breast cancer surgeries. Reconstructing an aesthetically pleasing breast has been a challenge. Various techniques to fill the breast defect or reconstruct the partial mastectomy defect are presently used, such as local wedge closure, local tissue rearrangement, the local advancement flap, thoracodorsal perforator flap, latissimus dorsi flap, silicone implant, and reduction mammoplasty. The authors described the use of the pectoralis major muscle with or without the pectoralis minor muscle as an innovation to fill the lumpectomy defects in the upper quadrants of the breast. Ten patients with breast cancer in whom the cancer measured between 2 and 4 cm were identified for the study, the prerequisite being that the tumor should be present in the upper quadrants of the breast. Patients with severe ptosis (grade 3) were excluded from the study. After lumpectomy, using the same incision, a pectoralis major muscle flap was harvested based on a thoracoacromial pedicle, rolled over like a ball, and used to fill the defect. A pectoralis minor muscle flap was supplemented in two patients in whom additional volume was required. After 9 months, cosmesis was evaluated by three independent judges using the visual analog scale. No patient had any flap necrosis; one patient had a minor wound infection. None of the patients had positive surgical margins for malignancy.


The latissimus dorsi muscle flap cannot be used to eliminate an empyema cavity in patients who have previously undergone posterolateral thoracotomy, because of the division of this muscle. Moreover, thoracoplasty alone cannot sufficiently eliminate an empyema cavity that includes the thoricacic apex, where space remains between the clavicle and the first rib. The authors constructed a flap from the pectoralis major and pectoralis minor muscles to eliminate empyema cavities in five patients who had undergone lobectomy or pneumonectomy via posterolateral thoracotomy from 3 months to 40 years previously. All five patients had bronchopleural fistulas, and because of the previous upper lobectomy or pneumonectomy, they had large empyema cavities including the thoracic apex. Open drainage thoracotomy was performed for severe infection, and intrathoracic transposition of the muscle flap with simultaneous thoracoplasty was carried out 7 to 124 weeks later. The pectoralis major and pectoralis minor muscle flap easily reached the apex space with sufficient obliteration of the empyema cavity. All patients remained free of empyema 12 to 85 months after thoracic closure.


The authors treated more than 300 patients during the past 20 years who had long-standing unilateral facial palsy with a cross-facial nerve graft and a free pectoralis minor muscle flap to the face. In this study the authors assessed the residual postoperative donor site morbidity in the chest. During the second stage of the operation, the medial and lateral pectoral nerves were divided at a proximal level from the plexus. Because of the common innervation of the two pectoral muscles, a consequent change in pectoralis major muscle function could be expected, but no study had been performed to determine whether this occurs. They performed a subjective and an objective study on a voluntary sample of 38 patients previously operated on for facial palsy with pectoralis minor muscle transfer. Cosmetic and functional outcomes were recorded. The subjective evaluation was obtained through a questionnaire; the objective evaluation was obtained through physical examination (inspection and palpation). They
assessed the following quantitative parameters: thickness of the muscle, arm muscle circumference, power produced at contraction, and muscle fiber activity. Subjectively, 6 patients reported a reduction in the force of the muscle and 10 patients noticed a change in muscular thickness at the site of the operation. Objectively, the results of the electromyogram were almost normal in all of the muscles sampled (17 patients). Occasionally, minor changes from the normal pattern were seen in the lower half of pectoralis major. The dynamometer adduction test showed a significant reduction in the force developed on the operated side when it was the dominant side, whereas no difference was shown in the group of patients who underwent operations on the nondominant sides. For the pectoral fold and the arm muscle circumference, no difference was found between the operated and nonoperated side.


Covering large defects in the axillary fossa can be challenging because of its complex shape. A variety of local skin, fasciocutaneous, and myocutaneous flaps have been described, with a number of inherent advantages and disadvantages. The use of the pectoralis minor muscle as a pedicled transposition flap has been described for immediate reconstruction of the breast, anterior shoulder reconstruction and the treatment of bronchopleural fistula. The authors described the use of a pedicled pectoralis minor muscle flap for soft tissue coverage of the axillary contents after wide excision of the axilla, which had not been previously reported.


Infected sternoclavicular joint is unusual, and treatment of this entity has not been standardized. The authors sought to characterize the current presentation and optimal management of this disease by retrospectively reviewing the records of the last 7 patients undergoing operation for supplicative infections of the sternoclavicular joint. The authors concluded that aggressive surgical management including resection of the sternoclavicular joint and involved ribs with pectoralis flap closure would appear to be the preferred treatment for all but the most minor infections of the sternoclavicular joint. This approach has minimal impact on upper extremity function.


The authors described the case of a patient undergoing resection of a large axillary and chest wall tumor that resulted in exposure of the brachial plexus and axillary vessels. They detailed their experience of the use of the pectoralis minor pedicled flap for the reconstruction of such a defect, providing excellent postoperative mobility of the axilla and minimal donor site morbidity.


The “babysitter” procedure, introduced by Terzis in 1984, combines cross-facial nerve grafting with segmental transfer of the hypoglossal to the affected facial nerve and can produce satisfactory to excellent results. In long-lasting paralysis, nonetheless, the babysitter procedure may need to be combined with a muscle flap (or flaps) for outcome upgrading, which was the focus of this study. Thirty-eight patients underwent the babysitter procedure over a 20-year period (1984 to 2003). Twenty patients had only the babysitter procedure, whereas 18 needed additional muscle flaps (up to three) to enhance function and cosmesis. These muscles included nine free (gracilis, pectoralis minor) and 20 regional (frontalis, mini-temporalis, platysma, digastric) muscles for distinct target needs: eye closure, smile restoration, and lower lip depression. All free muscles were transferred at the second stage of the babysitter procedure; regional muscles were also transposed later. All patients had upgrading of overall aesthetics and smile, whereas four maintained similar scoring for eye closure, and one maintained similar scoring for lip depression. All but two had secondary procedures to further enhance facial symmetry.

The authors performed anatomic study of the dimensions of the pectoralis minor muscle and its neurovascular supply in 10 adult human cadavers to evaluate the feasibility of microsurgical transplantation of a part of the muscle for thumb opposition reconstruction. Subsequently, a series of five patients underwent thenar reconstruction with the pectoralis minor muscle flap from December 2004 to October 2006. The transferred muscle was reinnervated with the third lumbrical branch of the ulnar nerve. Follow-up assessment showed that the patients recovered functional opposition of the carpometacarpal joint, with 24 degrees of pronation and a muscle power of M4 to M5. All patients were satisfied with the appearance of the reconstructed thenar eminence.
ANATOMIC LANDMARKS

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Section 6C

ANTERIOR THORAX

Lateral Intercostal Artery Perforator (LICAP) Flap

CLINICAL APPLICATIONS

Regional Use
Thorax
Breast
Sternum
Axilla

Distant Use
Head and neck
Upper extremity
Lower extremity
ANATOMY OF THE LATERAL INTERCOSTAL ARTERY PERFORATOR (LICAP) FLAP

Intercostal perforator and cutaneous supply of LICAP flap and variants

Flap options based on chest hemicircumference

Fig. 6C-1

**Dominant pedicle:** Posterior intercostal vessels
ANATOMY

Landmarks
The lateral intercostal artery perforator (LICAP) flap is a fasciocutaneous island based on the posterior intercostal neurovascular bundle.

Composition
Fasciocutaneous.

Size
24 × 14 cm.

Arterial Anatomy

Dominant Pedicle  
Posterior intercostal vessels

REGIONAL SOURCE  
Aorta.

LENGTH  
Vertebral segment: 8 cm; intercostal segment: 15 cm; intermuscular segment: 12 cm; rectus segment: 8 cm.

DIAMETER  
1 to 1.5 mm.

LOCATION  
There are nine pairs of intercostal arteries within the lowermost nine ribs. The vessels arise from the aorta and course beneath the inner aspect of each rib running anteriorly to then communicate with the anterior intercostal circulation arising from the internal mammary arteries. The vessels are divided for technical purposes into an 8 cm vertebral segment that runs from the aorta to the angle of the rib. Within this course this segment gives rise to a dorsal branch to the skin and a nutrient branch to the rib, as well as a minor collateral branch. The second segment is the intercostal component, which begins at the costal groove beyond the costal angle and extends around the chest to the insertion of the abdominal musculature on the ribs anterolaterally. At this point the vessels lie deep to the external and internal intercostal muscles, but superficial to the innermost intercostal and parietal pleura. This segment gives rise to five to seven myocutaneous perforators at 1 to 3 cm intervals along its course, each with a diameter of 0.8 mm. The main trunk of the vessel is 1.5 cm at the midaxillary line and gives off a large lateral cutaneous branch at this point. This exits anterior to the latissimus dorsi muscle. The lateral cutaneous branch divides into a large anterior and smaller posterior branch accompanied by sensory nerves. In 40% of patients this lateral cutaneous branch divides early, with the large anterior component running deep to external oblique for several centimeters before it emerges into the overlying skin. Damage to this can lead to flap compromise. A third segment of the intercostal artery is the intermuscular segment, 12 cm in length, which begins at the costal attachment of the abdominal musculature, extending to the lateral border of rectus abdominis. It passes between the internal oblique and transversus abdominis muscles. The final segment is the rectus portion, which lies superficial to the posterior rectus sheath, anastomosing with the deep epigastric circulation.

Venous Anatomy

Venous drainage is an exact mirror of the arterial circulation as venae comitantes accompanying the arteries. The vessels may be single or paired. They are 1 mm or less in diameter.

Nerve Supply

Motor  
The intercostal nerves send muscular branches to the intercostal muscles.

Sensory  
Intercostal nerves follow the perforating branch up into the skin posteriorly, laterally, and anteriorly.
VASCULAR ANATOMY OF THE LICAP FLAP

**Fig. 6C-2**  
A, Location of the lateral fat compartment captured in this flap. B, Anatomic study demonstrating the lateral fat compartment (*indicated in blue*). C, Cadaver dissection showing the right back–axilla region, revealing the main vascular pedicles. The locations of the intercostal perforators are indicated (*arrows to red markers*). D, A dominant intercostal perforator is shown among other smaller ones (*blue markers*). (A and B, courtesy Michel Saint-Cyr, MD; C and D, courtesy Moustapha Hamdi, MD.)
FLAP HARVEST

Design and Markings
The lateral intercostal artery perforator (LICAP) flap can be designed at any portion along the course of the posterior intercostal artery or from the anterior intercostal artery. The most common donor vessels are the posterior intercostals. Any perforating branch from the posterior intercostal artery can be used to supply the flap; the most common location is on the lateral chest. The flap is designed with the patient standing and is most often raised over the ninth to eleventh ribs. Doppler ultrasound is used to identify the perforator. The skin island is drawn with the posterior border of the flap lying at least 5 cm behind the posterior axillary line to ensure that the lateral cutaneous branch is incorporated within the flap. Although injection studies have demonstrated that flaps as large as 20 to 25 cm may be raised safely, 12 cm in diameter tends to be the limit that can be closed primarily. The flap is centered on the midaxillary line; the pedicle length ranges from 8 to 15 cm.

Fig. 6C-3  After its intermuscular course, the lateral cutaneous bundle emerges in front of the latsimus dorsi muscle, where it pierces the origin of the external oblique abdominis muscles. This branch divides after its intermuscular course into a larger anterior and smaller posterior branch, accompanied by the sensory lateral cutaneous branch.

Patient Positioning
The patient is placed in the lateral decubitus position with the arm free-draped into the field.
GUIDE TO FLAP DISSECTION
Loupe magnification is used for all dissections. The posterior incision is made first to allow for perforator identification. The incision is deepened to expose the latissimus dorsi muscle and incorporate the deep fascia to safeguard the contained vessels. Once the anterior border of the latissimus dorsi has been reached, the smaller posterior branch of the larger cutaneous branch can usually be found. This is followed to its bifurcation within the larger anterior branch. The flaps are usually designed spanning two or three ribs; this allows the segment of the largest of any of the lateral cutaneous branches to be chosen as the primary flap inflow. The vessels tend to gap slightly posteriorly beneath the anterior border of the latissimus dorsi muscle, and the latissimus must be retracted to follow the vessel down through the serratus anterior or the external oblique muscles, which have to be divided to gain access to the intercostal space.

**Fig. 6C-4** Surgical technique for the LICAP flap on the lower lateral part of the rib cage. **A,** After the anterior border of the latissimus dorsi muscle is visualized, the smaller posterior branch of the lateral cutaneous branch is identified. This branch is followed to find the bigger anterior branch. **B,** The origin of the external oblique abdominis muscle is elevated and split, and the latissimus dorsi muscle belly is retracted.
These intercostal muscles are freed from the lower border of the rib, thereby exposing the juncture of the lateral cutaneous branch with the posterior intercostal main trunk.

The periosteum is incised along the undersurface of the rib as it curves posteriorly. The anterior extension of the posterior intercostal beyond the junction of the lateral cutaneous branch is ligated, leaving the lateral intercostal vessel in continuity with its posterior intercostal main trunk. The flap is then ready for transfer. The remaining skin island is incised around the lateral cutaneous perforator.

**FLAP VARIANTS**

- Dorsal intercostal artery perforator (DICAP) flap
- Anterior intercostal artery perforator (AICAP) flap
Dorsal Intercostal Artery Perforator Flap

The dorsal intercostal artery perforator (DICAP) flap is based on the dorsal cutaneous branch of the posterior intercostal artery between the aorta and the angle of the rib posteriorly. The dorsal branch is 1.5 mm in diameter, and the largest vessel is found beneath the seventh rib. The next largest is the sixth rib; it is recommended that the flap be based overlying these two ribs. The perforator is located with Doppler ultrasound or indocyanine green (ICG) fluorescence imaging. The flap has a much shorter pedicle than the LICAP flap but can be useful for midline back defects. Dissection usually commences laterally and progresses medially. The pedicle length can be increased by dissecting through the paraspinal muscles.

![Paravertebral perforator source for DICAP flap](image)

Fig. 6C-5

Anterior Intercostal Artery Perforator Flap

The anterior intercostal artery perforator (AICAP) flap is based on the perforator arising from the anterior intercostal artery, the source vessel being the internal mammary (see the IMAP variant of the deltopectoral flap in Section 6A). The perforator is located with Doppler ultrasound or ICG fluorescence and lies 1 to 3 cm lateral to the sternum. The skin island is dissected in the subfascial plane until the perforator is identified. Depending on its location in the chest wall, the pectoralis major or rectus abdominis muscle is split, and the perforator is followed down to the source vessel. The largest internal mammary branches are found in the second to third interspaces. Pedicle lengthening can be achieved by harvesting the main internal mammary trunk with the perforator. A sensate flap can be elevated by including the intercostal nerve. Pleural damage must be avoided at all costs.

![Vascular source for AICAP flap](image)

Fig. 6C-6
ARC OF ROTATION
The LICAP flap can be rotated onto the chest, axilla, or breast based on its available pedicle length. The DICAP and AICAP flaps have a much more limited arc of rotation because of their short pedicle lengths.

Fig. 6C-7  Arc of rotation of the LICAP flap. More arc of rotation is gained by extending the skin design, and more freedom of placement is achieved with further pedicle dissection.

FLAP TRANSFER
Pedicle flaps are either tunneled or transposed into their adjacent defects. Free tissue transfers are transferred and anastomosed to their recipient vessels as dictated by the defect.

FLAP INSET
The flaps are inset using a two-layer closure. In free flap transfer it is imperative to ensure that there is no tension, kinking, or rotation of the pedicle after anastomosis.

DONOR SITE CLOSURE
The donor site is usually closed directly, particularly when the skin island diameter is less than 12 cm on the lateral chest. On the anterior or posterior chest, this becomes difficult when the defect is wider than 7 cm.
CLINICAL APPLICATIONS

This 59-year-old patient was admitted for a quadrantectomy with partial breast reconstruction for cancer of the right breast located at the superolateral quadrant.

Fig. 6C-8  A, Preoperative view.  B, Flap design with the mapped perforators.  C, The defect after the quadrantectomy.  D, The two perforators were found, one perforator (seen against green background) originated from the thoracodorsal vessels, and one LICAP in front of the anterior border of the latissimus dorsi muscle. The intercostal nerve was included in the flap.  E, The thoracodorsal perforator was clipped.  F, The flap was based on the intercostal perforator. The LICAP was totally deepithelialized and turn 180 degrees to the breast defect.  G, Postoperative view. (Case courtesy Moustapha Hamdi, MD.)
This 76-year-old woman had already undergone a large mastectomy and a latissimus dorsi flap reconstruction followed by radiation therapy. She developed a local recurrence that extended over the sternal region, so a radical excision and flap coverage were planned. She requested reduction of the contralateral breast. An AICAP flap was designed over the breast, part of which is usually incorporated in an inverted-T incision.

**Fig. 6C-9**  
A, The patient is seen preoperatively.  
B, Flap design and breast reduction pattern with a lateral pedicle. The defect measured 12 by 8 cm.  
C, The AICAP flap was designed over the medial part of the excised inverted-T skin pattern.  
D, The defect after the radical excision.  
E, The flap skin was incised.  
F, The AICAP flap was advanced with 90-degree rotation.  
G, The defect was closed with the AICAP flap, and the breast reduction was completed.  
H, The patient is seen postoperatively with complete wound healing. (Case courtesy Moustapha Hamdi, MD.)
This 56-year-old man was referred for defect closure after a large resection for dermatofibrosarcoma. The closure was performed using a DICAP flap.

![Fig. 6C-10 A, Preoperative view. B, The DICAP flap was designed around the mapped perforator. C, Complete wound healing was obtained. (Case courtesy Moustapha Hamdi, MD.)](image)

A patient underwent scar release after an axillary burn. The resulting defect was closed using a LICAP flap.

![Fig. 6C-11 A, The defect is shown, with the designed LICAP flap. The X indicates the mapped perforator. B, The flap was raised on two intercostal perforators. C, The flap was rotated 180 degrees, with complete defect coverage. (Case courtesy Moustapha Hamdi, MD.)](image)
Pearls and Pitfalls

- The major advantage of the LICAP flap is its thin, pliable consistency and long vascular pedicle with adequate but small vascular diameter for anastomosis.
- The flap can be designed as a sensate island with two or three fascicles of the intercostal nerves supplying the entire flap.
- Venous drainage is usually good, but for larger flaps, additional segmental veins can be dissected to improve venous outflow.
- The thin nature of the flap makes it particularly useful for the neck, face, and dorsum of the hand.

EXPERT COMMENTARY
Moustapha Hamdi

This chapter provides an overview of the anatomy and surgical technique of the intercostal perforator flaps. Most of these can be used as pedicled as well as free flaps. The use of the intercostal neurovascular pedicle to supply a sensory skin flap was first suggested by Esser and later by Daniel and Williams. The clinical use of such flaps was then described by many others as myocutaneous, with random extensions beyond the thoracic cage. Badran and colleagues were the first to describe the harvesting of a lateral intercostal fasciocutaneous free flap based on one neurovascular bundle, sparing the abdominal musculature—this being the first perforator-based intercostal free flap. I have been using this flap since 2000, but as pedicled intercostal perforator flaps for many clinical indications.

indications

Many patients with breast or thoracic defects who were traditionally treated with a latissimus dorsi myocutaneous flap are suitable candidates for pedicled intercostal perforator flaps. The indications are summarized as follows:

1. Breast surgery
   - Partial breast reconstruction, whether immediate or after wider excision in cases of histologically involved margins for tumors located at the lateral quadrants
   - Correction of breast deformity after breast-conserving surgery (tumorectomy and radiation therapy)
   - Salvage procedure after significant partial necrosis of a free flap for breast reconstruction
   - Postmastectomy breast reconstruction in combination with an implant
   - Autologous breast augmentation; in particular, for patients after massive weight loss

2. Axillary defects (such as burn contractures and hidradenitis)

3. Skin coverage of sternal and paramedial defects

4. Upper dorsal defects

Continued
Advantages and Limitations
The flap provides sizable skin and fat flaps based on a single perforator; furthermore, there is only a minimal decrease in flap volume postoperatively as opposed to the latissimus dorsi myocutaneous flap which can lose up to 30% of volume secondary to muscle atrophy. The donor site can be closed primarily after harvesting up to a 20 by 10 cm flap, depending on skin laxity. Significantly there has been no seroma formation at the pedicled perforator flap donor site, and patients have a more rapid rehabilitation course. Patients are also less likely to complain of pain, and subjectively, they appear more comfortable after pedicled flaps. Another important consideration in selecting pedicled perforator flaps is the potential to harvest the latissimus dorsi muscle flap at a later date.

Perforator flaps are not usually indicated in cases of postmastectomy autologous breast reconstructions because of a lack of sufficient volume, nor can pedicled flaps easily reach three-dimensional defects located in the medial quadrant. However, additional volume can be obtained by fat injection in the flap or an implant behind the flap. Perforator flap harvest is initially more difficult than traditional myocutaneous latissimus dorsi flap harvesting and necessitates some training with the attendant learning curve.

Anatomic Considerations
The basic anatomy of the intercostal bundle was extensively described in the study of Kerrigan and Daniel. However, the perforator anatomy, their locations, and distribution have not been investigated until recently. Depending on their origin, the intercostal perforator flaps can be classified as posterior (dorsal), lateral, or anterior intercostal artery perforator (DICAP, LICAP, AICAP) flaps.

In our cadaver study, the anatomy of LICAP flap was investigated. All intercostal perforators located between the lateral border of the pectoralis major muscle and the anterior border of the latissimus dorsi muscle were identified. A mean value of 7.83 perforators per cadaver and 3.91 perforators per side were found. The highest concentration of intercostal perforators was found between the fifth and the eighth intercostal spaces (88.4%). The mean distances of intercostal perforators from the anterior border of the latissimus dorsi muscle varied from 2.67 to 3.49 cm. A dominant perforator was identified in 93.6% dissected sides. No dominant perforators were identified in the third intercostal space. Retrograde dissection of the dominant perforator revealed that it travels obliquely under a slip of the origin of the serratus anterior muscle into the intercostal space deep to the internal and external intercostal muscles. Once deep to the intercostal muscles, it emerges from the subcostal groove. The dominant perforator typically had a smaller posterior branch, which bifurcated above the serratus anterior muscle. This branch was found to communicate with the thoracodorsal perforators or serratus anterior vessels. When it bifurcated under the serratus anterior muscle (in 10% of cases), it had a similar diameter to the anterior branch.

Recommendations
Planning
The intercostal island flap is typically based on the posterior intercostal vessels, but the flap can be designed on any segment of the course of the posterior intercostal artery or from the anterior intercostal artery. Obviously, this flap can be harvested as a perforator flap, sparing the muscle and fascia. The largest perforator is based on the lateral branch of the posterior intercostal artery, but an intercostal perforator flap can be dissected on any located perforator arising from the intercostal vessels. The flap can be used as a pedicled flap to reconstruct a distant defect of the thorax, sacrum, and axillary region or as a free flap.
This flap is designed on the lateral side of the flank with the patient standing or side-lying. Perforators are located with greater ease with Doppler. In a planned pedicle flap, its position is based on the location of the recipient defect. Depending on the indications and the location of the defect, the flap is designed as a transposition, rotation, or V-Y advancement flap. The width of the flap should allow primary closure of the donor site.

**Technique**

Dissection of this flap should be done using loupe magnification. A posterior incision is made first, with an anterior extension at its lower end to explore the perforators and allow easy elevation of the flap. The incision is deepened to expose the latissimus dorsi muscle. It is safer to include the deep fascia in the flap to avoid accidental injury to the posterior branches of the bundle. After visualization of the anterior border of the latissimus dorsi muscle, the surgeon identifies the smaller posterior branch of the lateral cutaneous branch. This branch is followed to find the bigger anterior branch. Dissection proceeds by retracting the deep muscle (the external oblique muscle or the serratus anterior, depending on the location of the defect and flap). The external and internal intercostal muscles are then cut, and the junction of the lateral cutaneous branch with the main bundle is found.

If a longer pedicle is required, the intercostal vessels should be dissected within the costal groove. At this level, the dissection is more difficult and necessitates great care to avoid injury to the vessels in the costal groove; therefore the dissection of the pedicle usually stops at this level. The lateral cutaneous nerve can be stripped from the main intercostal nerve for any desired distance to make the flap sensate. The superior border of the flap is then marked and incised, taking into consideration both the width to cover the defect and primary closure of the donor site. The rest of the flap is elevated easily above the muscle fascia until the dissection is close to the entrance of the lateral branch into the skin. The plan is then changed to include the fascia in the flap for safer dissection.

**Postoperative Care**

No dressing is required on the flap. Pressure should be avoided on the area at which the perforator enters the flap. All our patients receive intravenous piracetam 12 g for 24 hours and as a 20% solution orally 25 ml four times a day for an additional 5 days. This drug acts to increase the viability of the distal parts of the flap by increasing capillary blood flow.

**Complications**

Intercostal perforator flaps have usually robust blood supply. On the other hand, extending the flap beyond the angiosome territory may lead to partial flap necrosis. Although an intercostal perforator flap could be designed in a different direction, horizontal flap's design provides a larger flap because of the interconnection between consequent perforators that arise from the same vascular intercostal arcade. Therefore the intercostal perforator flap is better designed parallel to the rib direction when a large skin flap is needed.

The flap has enough venous drainage but if a large flap is needed, additional venous drainage may be required through another intercostal bundle above or below the chosen one. Flap hypersensitivity has been reported by some patients after harvest of the intercostal perforator flap. This hypersensitivity may last 3 to 6 months before resolving.

*Continued*
Take-Away Messages

Flap dissection is quick and easy. This flap is large and usually quite thin, or it can be thinned preoperatively. The pedicle is short; however, a longer pedicle can be obtained with intracostal groove dissection. It has several indications for trunk reconstruction, depending on the level of the costal bundle. The flap is sensitive through the lateral intercostal nerve, which has two to four fascicles to supply the entire flap.

References

1. Esser J. [Biological or artery flaps of the face] Institut Esser de Chirurgie Structurale Monaco 1931.
**Bibliography With Key Annotations**


Lateral intercostal artery perforator flaps are based on intercostal perforators that arise from the costal groove. The intercostal perforators were dissected in 24 fresh cadavers and evaluated in a field that extended between the third and the eighth intercostal spaces and between the latissimus dorsi and pectoralis major muscles. Their relationship with the anterior border of the latissimus dorsi muscle and the serratus anterior vessels was investigated. A mean of 3.91 perforators per side was found; 88.4% of the intercostal perforators were found between the fifth and eighth intercostal space level. Mean distances of intercostal perforators to the anterior border of the latissimus dorsi muscle ranged from 2.67 and 3.49 cm. The largest or dominant perforator was most frequently found in the sixth intercostal space (38.6%) at an average of 2.5 to 3.5 cm from the anterior border of the latissimus dorsi muscle. In 10 of 47 sides (21%), vascular connections were found between the serratus anterior branch and the intercostal perforators. The connection was observed more frequently in the seventh and the sixth intercostal spaces, in 38% and 30% of cases, respectively. This vascular connection enables harvest of a serratus anterior artery perforator flap.


The intercostal vessels form an arcade between the aorta and the internal mammary vessels. Different pedicled perforator flaps can be raised on this neurovascular bundle to cover defects on the trunk. They are classified as following: dorsal intercostal artery perforator flap (DICAP); lateral intercostal artery perforator (LICAP); and anterior intercostal artery perforator (AICAP) flap. Between 2001 and 2004, 20 pedicled (ICAP) flaps were harvested in 16 patients. The indications were immediate partial breast reconstruction in eight patients who had a quadrantectomy for breast cancer; midline back and sternal defects in three patients who had radical excisions for a dermatofibrosarcoma or malignant melanoma; and autologous breast augmentation (four bilateral and one unilateral flap) in five postbariatric surgery patients. The average flap dimension was 18 by 8 cm² (range 8 by 5 to 24 by 12 cm²). There were two DICAP flaps, two AICAP flaps, and 16 LICAP flaps. All but two flaps were based on one perforator. Mean harvesting time was 45 minutes for a single flap. Bilateral breast augmentation with a LICAP flap necessitated a longer operative time (range 2 to 3 hours), depending on whether it was combined with mastectomy. Complete flaps survival was obtained. All donor sites were closed primarily.


Thirteen patients underwent conservative breast surgery (CBS) reconstructions with an ICAP flap. These flaps were raised from adjacent tissue located on the lateral and thoracic region and based on perforators originating from the costal and muscular segment of the intercostal vessels. The technique was indicated in patients with small to moderate volume breasts. The mean time of follow-up was 32 months. Flap complications were evaluated, and information on patient satisfaction was collected; 61.5% had tumors located in the lower-outer quadrants, and 69.2% had tumors measuring 2 cm or less (T1). Complications occurred in three patients (23%), including wound dehiscence in two and fat necrosis in one. All cases were treated by conservative approach with a good result. No flap loss or wound infection were reported; 90% of patients were either satisfied or very satisfied with their result.
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>The serratus anterior is a thin, broad muscle on the lateral chest wall between the ribs and the scapula. The usable portion of the muscle lies between the anterior free border of the latissimus dorsi and the inferolateral border of the pectoralis major, extending inferiorly as low as the ninth rib.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>20 × 15 cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>Broad origin consists of multiple leaflets, each arising from a separate rib, passing obliquely upward posteriorly before blending into a wide muscle belly that inserts into the anteromedial edge of the scapula.</td>
</tr>
<tr>
<td>Insertion</td>
<td>Medial border of the anterior surface of the scapula.</td>
</tr>
<tr>
<td>Function</td>
<td>Protracts the scapula forward and stabilizes the scapula against the chest during arm motion. Paralysis of the muscle creates unsightly winging of the scapula.</td>
</tr>
<tr>
<td>Composition</td>
<td>Broad, flat sheet of muscle arising from the ribs and inserting onto the scapula. The muscle is usually raised in isolation, but its blood supply can support fascial, cutaneous, and bony components.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type III.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Lateral thoracic artery.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Serratus branches of thoracodorsal artery.</td>
</tr>
</tbody>
</table>
Section 6D

ANTERIOR THORAX

Serratus Flap

CLINICAL APPLICATIONS

Regional Use
- Thorax
- Breast
- Intrathoracic cavity
- Axilla
- Posterior trunk

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Functional muscle
- Facial reanimation
**ANATOMY OF THE SERRATUS ANTERIOR FLAP**

**Fig. 6D-1**

**Dominant pedicles:** Lateral thoracic artery; serratus branches of thoracodorsal artery

- **A**
  - Muscle origin and insertion

- **B**
  - Lateral thoracic artery
  - Serratus branches of thoracodorsal artery

- **C**
  - Long thoracic nerve
**ANATOMY**

**Landmarks**
The serratus anterior is a thin, broad muscle on the lateral chest wall between the ribs and the scapula. The usable portion of the muscle lies between the anterior free border of the latissimus dorsi and the inferolateral border of pectoralis major, extending inferiorly as low as the ninth rib.

**Composition**
Broad, flat sheet of muscle arising from the ribs and inserting onto the scapula. The muscle is usually raised in isolation, but its blood supply can support fascial, cutaneous, and bony components.

**Size**
20 × 15 cm.

**Origin**
Broad origin consisting of multiple leaflets, each arising from a separate rib, passing obliquely upward posteriorly before blending into a wide muscle belly that inserts into the anteromedial edge of the scapula.

**Insertion**
Medial border of the anterior surface of the scapula.

**Function**
Protracts the scapula forward and stabilizes the scapula against the chest during arm motion. Paralysis of the muscle creates unsightly winging of the scapula.

**Arterial Anatomy (Type III)**

**Dominant Pedicle**
*Lateral thoracic artery*

**Regional Source**
Arises from the axillary artery.

**Length**
6 to 8 cm.

**Diameter**
2 to 2.5 mm.

**Location**
Direct branch of the axillary artery that runs along the anterolateral surface of the muscle and descends to the level of the fifth intercostal space.

**Dominant Pedicle**
*Serratus branches of thoracodorsal artery*

**Regional Source**
Axillary artery.

**Length**
6 to 8 cm.

**Diameter**
2 to 3 mm.

**Location**
The thoracodorsal artery, a continuation of the subscapular trunk, sends two to four branches to the serratus just before entering the latissimus dorsi. The thoracodorsal pedicle to the serratus muscle lies 6 to 7 cm posterior to the lateral thoracic pedicle.

**Venous Anatomy**
Single veins accompany the arterial circulation; the average venous diameter is 1.5 to 3 mm.

**Nerve Supply**

**Motor**
C5–C7 roots of long thoracic nerve.

**Sensory**
T2–C4 segmental intercostal nerves.
VASCULAR ANATOMY OF THE SERRATUS FLAP

Deep surface of serratus anterior and latissimus dorsi flaps

Fig. 6D-2

Dominant pedicles: Lateral thoracic artery ($D_1$); serratus branches of thoracodorsal artery ($D_2$)

d, Latissimus dorsi muscle; $n_1$, long thoracic nerve; $n_2$, thoracodorsal nerve; s, serratus muscle; t, thoracodorsal artery
**Fig. 6D-2**

**Dominant pedicles:** Lateral thoracic artery ($D_1$); serratus branches of thoracodorsal artery ($D_2$)

d, Latissimus dorsi muscle; s, serratus muscle; t, thoracodorsal artery
FLAP HARVEST

Design and Markings
The serratus muscle is approached either through an oblique lateral chest wall incision or a vertical incision down the lateral chest wall. The anterolateral chest skin between the anterior and posterior axillary lines is included in the territory of this flap. In a muscular individual, the muscle interdigitations can be clearly seen on the lateral chest wall. In most women, the lateral breast mound obscures these features. It is usual to harvest only the lowermost three or four segments of the muscle, leaving the upper fibers for scapula stability.

With forceful contraction of the latissimus muscle, the anterior margin of the latissimus at the posterior axillary line can be seen or palpated and is marked. With forceful contraction of the pectoralis muscle, the lateral borders of the pectoralis at the anterior axillary line are visualized and marked. The anterolateral portion of the serratus muscle and its skin island lie in this triangle. The remainder of the muscle lies deep to the latissimus and extends posteriorly to insert onto the deep surface of the medial border of the scapula, which is marked to denote the posterior extent of the muscle. Skin is almost never harvested with this flap.

Patient Positioning
The patient is placed in the lateral decubitus position on a beanbag support with an axillary roll placed to the dependent axilla. The ipsilateral upper extremity is free draped into the field using an impervious stockinette wrap to allow intraoperative manipulation of the arm during dissection. It is possible to harvest the anterior portion of this muscle with the patient in the supine position and the arm abducted to 90 degrees at the shoulder.
GUIDE TO FLAP DISSECTION

The skin is incised either vertically or obliquely along the side of the chest between the anterior border of latissimus dorsi and the inferolateral border of the pectoralis major muscle.

Dissection is carried directly down to the muscle, which is easily seen subcutaneously. The surgeon must avoid damaging either of the two vascular pedicles during exposure, because both sets of vessels lie on the superficial surface of the muscle. The long thoracic nerve should be identified early in the dissection to prevent injury. The thoracodorsal pedicle is identified posteriorly, and the number of slips to be elevated is marked. In general, the upper slips of the serratus are best based on the lateral thoracic pedicle; the lower portion is based on the thoracodorsal pedicle.
It is easier to elevate a flap based on the thoracodorsal pedicle, and most of the lower slips (four to nine) will survive on this pedicle. To preserve function and eliminate winging of the scapula, only the lower three or four slips should be harvested as a flap. The pedicle of choice for elevation of the flap either as a standard muscle flap or for microvascular transplantation is the thoracodorsal pedicle. With the thoracodorsal pedicle identified, the muscular digitations are dissected anteriorly from their rib origin using cautery as the attachments are densely adherent, and separation can be bloody. The plane of dissection is supraperiosteal and is never well defined.

Dissection is continued from anterior to posterior toward the scapula. Posteriorly the muscle segment is divided and the flap elevated from below upward. The lateral thoracic nerve, the motor nerve of the muscle, is found on the superficial surface of the serratus. It joins the thoracodorsal pedicle at the level of the sixth rib and runs distally with it. It is important to preserve this nerve and its innervation of the upper digitations to prevent winging of the scapula. Once the muscle has been isolated, the vessels are dissected from below upward, preserving the long thoracic nerve.
FLAP VARIANTS

- Composite serratus-latissimus flap (chimeric flap)
- Serratus fascial flap
- Myoosseous flap

Composite Serratus-Latissimus Flap

A very large combined serratus-latissimus flap can be elevated based on the thoracodorsal vessels. The standard skin incision for the serratus or latissimus muscle is made. Both muscles are identified and elevated in the customary fashion. The branches of the thoracodorsal artery to the serratus are preserved so that the thoracodorsal artery serves as the vascular pedicle for both flaps. An even larger extension can incorporate the scapular or parascapular skin islands based on the circumflex scapular branches arising from the subscapular axis.
Serratus Fascial Flap (Lateral Thoracic Fascia)

A flap based on the serratus branches of the thoracodorsal artery and the fascia overlying the serratus anterior and deep to the latissimus dorsi is elevated. This is a very useful thin fascial flap for distant coverage. The standard incision for elevation of the serratus flap is made, and the lateral edge of the latissimus dorsi muscle identified. This edge is elevated and the underlying fascia and serratus muscle are exposed. The thoracodorsal artery is identified proximally, and branches coursing medially toward the serratus are identified and preserved. The fascial flap to be elevated is then outlined and incised.

This very thin flap is dissected off the underlying serratus anterior muscle. Dissection continues from distal to proximal and includes the branches of the thoracodorsal artery. Branches extending into the serratus muscle are cauterized with the bipolar electrocautery unit. Larger branches are isolated, clamped, divided, and ligated. Separating the fascia from the underlying serratus muscle can be a bloody dissection. The dissection is best performed from distal to proximal. The branches of the thoracodorsal to the latissimus muscle are ligated and divided. Care should be taken to preserve the long thoracic nerve. The fascia is dissected away, leaving the nerve intact.
Myosseous Flap
Portions of the ribs at the site of the origin of the muscle may be elevated as an osteomuscular flap. Most commonly the fifth or sixth rib is included with the serratus muscle for such an osteomuscular flap. Flap elevation proceeds as described for the standard flap, but an extrapleural dissection of the fifth or sixth rib is done, leaving the muscle slip attached to the elevated portion of rib.

In addition to vascularized rib, it is possible to harvest a portion of the inferolateral border of the scapula. There is a distinct vascular pedicle, the angular branch, as described by Coleman and Sultan, which originates from the branch of the thoracodorsal vessel crossing to the serratus in 42% of patients and from the thoracodorsal directly in 58% of patients. This angular branch and associated veins supply the inferolateral border of the scapula, which can be included with the serratus as vascularized bone. However, this variant is not commonly used, because other flaps have less morbidity.
ARC OF ROTATION

Standard Flap

Based on the thoracodorsal pedicle, the flap has a long arc of rotation reaching the chest wall, shoulder, axilla, and back. It will also reach the intrathoracic cavity. Division of the thoracodorsal branch to latissimus dorsi will increase the anterior arc of rotation based on the thoracodorsal vessels. Division of the lateral thoracic pedicle will increase the posterior arc.

Fig. 6D-8

Anterior arc to neck and thorax

Arc to posterior trunk

Lateral arc into thoracic cavity
**FLAP TRANSFER**
The flap is transferred to its recipient site based on the location of the defect. When pedicled into the thoracic cavity, it is helpful to remove at least one or two rib segments as close as possible to the origin of the vascular pedicle to allow easy passage into the pleural space without risking kinking or compression of the flap’s blood supply.

**FLAP INSET**
The muscle is inset based on the requirements of the recipient site. Given the tendency of the muscle fibers of the origin to become frayed during elevation, sutures should be placed using a taper needle and should be tied down gently to prevent further damage to the muscle fibers.

**DONOR SITE CLOSURE**
A linear or curvilinear skin closure is usually performed at the donor site, with appropriate drainage to the wound bed.

**CLINICAL APPLICATIONS**
This 65-year-old woman underwent right lower lobectomy for lung cancer. She developed a stump leak with bronchopleural fistula. She was returned to the operating room for fistula repair and coverage of the stump with a pedicled serratus flap to help seal the bronchial stump closure. She healed successfully with no recurrent fistula formation or empyema.

*Fig. 6D-9*  
**A,** Thoracotomy wound following rib resection for insertion of a serratus flap to seal a bronchopleural fistula repair. **B,** The pedicled serratus anterior flap tunneled into the chest through a rib resection. (Case supplied by GJ.)
This 58-year-old woman developed a dermatofibrosarcoma protuberans of her left lateral leg above the ankle. She was referred for radical resection and free flap closure. At the time of resection, her distal fibula and extensor tendons were exposed. Coverage was performed using a free serratus anterior flap anastomosed to the anterior tibial vessels proximal to the defect. The flap was skin grafted to complete closure. She healed primarily and had had no recurrence at 2 years after surgery.

Fig. 6D-10  A, Open wound of the lateral lower leg with exposed tendons and bone after sarcoma resection. B, Serratus anterior flap anastomosed to the anterior tibial vessels proximal to the defect. C, The skin grafted serratus flap achieved wound closure. The patient healed uneventfully. (Case supplied by GJ.)
This woman required a functional muscle transplantation for reconstruction of the paralyzed right side of her face. A two-stage facial reanimation with a serratus flap was planned.

Fig. 6D-11  A, A cross-face sural nerve graft was placed between the contralateral buccal branches of the facial nerve (left side) to the preauricular region of the paralyzed right side of her face. B, Three inferior slips of serratus muscle were elevated as a functional muscle flap for transplantation to the right side of her face. Note that the proximal motor nerve fibers to the superior slips have been left intact. C, Vascular pedicle anastomosed to the facial artery and vein. Long thoracic nerve anastomosed to the distal end of the sural cross-nerve graft. D and E, The patient is seen at 6 months postoperatively. The innervated serratus muscle has restored facial animation with adequate symmetry and muscle support to the lower third of the face in repose. (Case supplied by G.J.)
This 59-year-old man had a history of squamous cell carcinoma of the oral cavity. He presented with a persistent salivary fistula 6 months after surgical resection, cervical lymph dissection, and postoperative radiation therapy. These difficult cases are best reconstructed with aggressive debridement and muscle flaps to add needed vascularity and fill dead space to allow healing. A serratus flap was chosen, because it would supply a small amount of muscle with low morbidity.

Fig. 6D-12  A, The preoperative defect. The entire fibrinous tract required debridement to bleeding tissue. B, The planned serratus flap. Only the lower three slips will be taken to maintain scapular function. C, Flap dissection was easily accomplished as the vascular pedicle lies superficially on the muscle and is readily seen and protected. D, After inset. The muscle was left intraorally to remucosalize, and a split-thickness skin graft was placed to maximize postoperative contraction of the graft. Note how much irradiated skin was removed to accomplish complete debridement. E, The patient is seen 4 months postoperatively. There were no further problems with fistula or infection. (Case supplied by MRZ.)
This 65 year-old man had a history of lung cancer and presented with a bronchopleural fistula after a pneumonectomy and irradiation. Not surprisingly, once the old thoracotomy was reopened and explored, the latissimus dorsi muscle had been completely divided and was not available for reconstruction. Fortunately, the serratus muscle was still intact and available for intrathoracic transposition to bolster the bronchopleural fistula repair.

**Fig. 6D-13**  
A, The serratus muscle was harvested in its entirety, based on the serratus branches of the thoracodorsal pedicle. B, After intrathoracic transposition to the bronchial stump site. Normally, a rib is resected for access to the chest, the closest rib to the pedicle origin, the better. In this case, the previously created pleural window at the fourth rib was used and was adequate for the repair. (Case supplied by MRZ.)

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**Pearls and Pitfalls**

- Early identification and preservation of the thoracodorsal vessel, lateral thoracic vessels, and long thoracic nerve are essential. Once the vessel and its branches to the serratus muscle have been identified, the rest of the dissection proceeds rapidly.

- Winging of the scapula will result if the entire muscle is harvested or denervated. However, segments of the muscle can be elevated to avoid functional deficits and winging of the scapula. Lower digitations are preferred.

- Any tunnel that is formed must be large enough to avoid vascular compromise.
EXPERT COMMENTARY
Glyn Jones

Indications
The serratus anterior muscle has most commonly been used as a minor addition to breast reconstruction at the time of placement. The muscle has a reliable blood supply, particularly when it is based on the thoracodorsal crossing branch. It is extremely important to protect the long thoracic nerve supply to the uppermost leaflet of the muscle to prevent winging of the scapula. Dissection of the anterior portion of the muscle at its costal origins is less than satisfying, because the fibers often fray during dissection. Dissection is certainly best performed with cautery rather than with scissors. Using this flap as a myoosseous variant does not provide very well vascularized bone, although inclusion of the tip of the scapula on the angular artery can give a more reliable reconstruction for mandibular bridging. Elevation of the serratus fascia can provide useful lateral coverage of an expander or implant placed at the time of immediate breast reconstruction, but the use of acellular dermal matrices is rapidly replacing this technique.

Recommendations
Use of the serratus anterior is particularly valuable during intrathoracic reconstruction, when the latissimus muscle has often been transected by a previous thoracotomy. Thoracic surgeons are increasingly attempting to preserve the serratus anterior muscle during thoracotomy to leave it as a viable reconstructive option for the future. When using the muscle within the pleural space, it is usually necessary to resect a portion of one or two ribs laterally to provide an adequate-sized window through which the muscle may pass without causing compression of the pedicle.

Bibliography With Key Annotations

The authors reported a retrospective analysis of 65 consecutive patients. Intrathoracic transposition of the serratus anterior (SA) muscle flap was used alone or in association with other flaps and/or thoracoplasty in patients not amenable to lung resection and/or decortication. The SA was used alone in 16 patients and in combination with other flaps in 49 patients. In 62 patients, the flap was mobilized using both the thoracodorsal branch and the lateral thoracic vessels. Associated limited rib resection was performed with an average of 4.9 resected ribs per patient. Mortality was 5% (three patients); two other patients (3%) developed recurrence of the intrathoracic infection and required reoperation. Minor local complications were encountered in three patients (skin necrosis, two cases, and external thoracic fistula, one case). Hospitalization ranged from 4 to 172 days. There was mild impairment of shoulder mobility in five patients, but no case of true winged scapula. Analysis of the preoperative and postoperative values of the vital capacity and forced expiratory volume (FEV1) showed no statistically significant difference.

The serratus anterior and rib myo-osseous composite flap provides vascularized muscle and bone on a single long pedicle, and because the flap is thin and easily contoured, it is ideal for reconstruction of defects such as full-thickness defects of the calvaria. The authors report on a modified subperiosteal technique that minimizes donor site mobility while still maintaining the vascularity to the ribs.


The authors reported a case of a latissimus dorsi musculocutaneous flap with microvascular venous super-charging in an acute ligation of the thoracodorsal vascular pedicle. Through their experience with this case, they have questioned a common belief that the flap will survive without the thoracodorsal vessels intact. They noted that risk is minimized when rotation of the flap takes place several weeks after ligation of the vessels. However, they did not think it is prudent to transfer a latissimus flap of significant size immediately after ligation of the thoracodorsal vessels, unless the vascular supply is enhanced.


The authors discussed the successful use of the serratus anterior free muscle flap to obliterate a recurrent oroantral fistula in a 39-year-old man who had sustained a high-velocity impact to the right side of his face 19 years previously and had undergone multiple corrective surgeries. There was no complication from the serratus anterior free flap surgery, and no postoperative scapular winging. The serratus anterior muscle is a versatile flap and ideal for various defects. It should be considered for obliteration of oroantral fistulas when no local or regional tissue is available because of previous surgery or trauma.


Coverage of exposed functional structures such as tendons, bones, vessels, or nerves at the dorsal and palmar surface of the hand requires thin, supple tissue to provide adequate range of motion and a satisfying aesthetic result. This retrospective study evaluated the functional and aesthetic results after coverage of the hand with free fascial flaps. From 1994 to 2002, 14 patients underwent free fascial flap coverage of the hand with four temporoparietal fascia flaps and 11 serratus fascia flaps. Eight patients were available to be reexamined and answered a questionnaire about their satisfaction with the functional and aesthetic results. Mean follow-up was 41.7 months. Average active range of motion of the hand, functional improvement, and the aesthetic result were satisfying in all follow-up patients. No secondary debulking or other contouring procedures were required. We recommend the use of free fascial flaps as a valuable alternative to fasciocutaneous or muscle flaps, since the functional results are excellent, no additional procedures were necessary, and the aesthetic results are appealing.


In reconstructing a defect on the dorsum of the hand, with the extensor tendons exposed or even missing, functional as well as cosmetic goals are of major importance. The authors presented three cases of extensor tendon reconstruction, combined with soft tissue reconstruction, with the free serratus fascia flap, the connective tissue over the serratus muscle, for dorsal hand coverage. The flap consists of thin and well-vascularized pliable tissue, with gliding properties excellent for covering exposed tendons. It is based on the branches of the thoracodorsal artery, which are raised in the flap, leaving the long thoracic nerve intact on the serratus muscle. Coverage of the flap with split-thickness skin graft is done immediately. The free serratus fascia flap is an ideal flap for dorsal hand coverage when the extensor tendons are exposed, especially because of low donor-site morbidity.

The authors presented their experience in surgical reconstruction of bone lesions in posttraumatic bone defects, pseudarthrosis, and osteitis by using the free serratus anterior rib flap. The flap was used in 12 cases: 7 in the upper limb and 5 in the lower limb. The overall immediate success rate in our series was of 91.7%. They had only one failure, from venous thrombosis. In all successful cases, the rib showed good integration. This procedure seems to be very useful in the reconstruction of small and medium bone defects, especially in the upper limb.


Because of its consistent anatomy, long vascular pedicle, malleability, low complication rate, and low donor site morbidity, the authors prefer serratus anterior transposition muscle flaps for prophylactic coverage of irradiated bronchi and treatment of bronchopleural fistulas. They described surgical technique and outcomes. Serratus anterior transposition muscle flaps can be performed with minimal morbidity and minimal impairment of upper extremity function.


The combined latissimus dorsi and serratus anterior flap has been employed for large defect reconstruction and has been shown to be reliable. These flaps are based on the subscapular-thoracodorsal vascular pedicle that usually supplies both muscles. In the case reported, serratus anterior possessed an anomalous arterial supply totally independent of the subscapular pedicle. The latissimus dorsi and serratus anterior muscles were used as a combined flap to reconstruct a massive thigh defect. The combined flap required two arterial anastomoses.


Spontaneous bronchopleural fistula after childhood empyema remains a surgically challenging condition to treat and is associated with high morbidity. Four children with pyopneumothorax and associated spontaneous infective bronchopleural fistula are reported. Drainage of the empyema by thoracotomy was performed, as well as limited decortication and suturing of a raised digitation of serratus anterior around the fistula to achieve a successful outcome. The surgical technique of raising a serratus anterior digitation flap was described.


Large maxillary defects ideally require reconstruction with a free flap. Varied classifications have been reported to describe maxillary/orbital defects. The authors reported their experience with free flaps in treating large maxillary defects using composite tissue of serratus anterior muscle and the angle of the scapula. Eleven patients (six men and five women; age range 42 to 69 years) were studied retrospectively and the outcome recorded. The authors concluded that the composite flap is versatile enough to reconstruct maxillary defects of various sizes.


Major ablative surgery in the head and neck region may create composite defects involving the oral mucosa, bone, and the overlying facial skin. The large surface area and the three-dimensional nature of these defects pose a difficult reconstructive challenge requiring adequate bone and large, positionally versatile skin flaps. From September 1993 to May 2000, 19 patients with through-and-through osteocutaneous defects of the mouth and face underwent reconstruction with composite subscapular artery system flaps. Ten variants of scapular osteocutaneous flaps, eight latissimus dorsi with serratus
anterior and rib osteomyocutaneous flaps, and one combination of an osteocutaneous scapular and osteomyocutaneous latissimus dorsi flap were used. Mean dimensions were skin 54.4 cm², mucosa 56.2 cm², and bone 8.2 cm. Ischemic complications occurred in three patients, including one total flap failure and one failure of the bony component, both in patients who had previously undergone radiation therapy. The third flap was successfully salvaged. No significant long-term donor site morbidity was noted.


Through a retrospective medical record review, the authors assessed complications and outcomes associated with latissimus-serratus-rib free flap oromandibular and midface reconstruction. Twenty-eight patients with segmental resection of the mandible were identified, and one patient with combined resection of the mandible and maxilla after excision of neoplasms of the oral cavity, who were poor candidates for fibula free flap reconstruction. Twenty-seven latissimus-serratus-rib osteomyocutaneous free flap reconstructions and two serratus-rib osteomuscular free flap reconstructions were performed. There were no perioperative free flap failures. Delayed partial rib graft resorption occurred in one patient 33 months after free flap transfer for maxillary reconstruction. Among 28 cases of mandibular reconstruction, one case of bone graft nonunion was noted after 57 months. All other cases achieved successful restoration of mandibular continuity. Donor site morbidity was well-tolerated in all patients.


This article reported the benefits of the serratus anterior flap, with or without latissimus dorsi muscle. It can provide a large composite osteomyocutaneous flap for one-stage reconstruction of three-dimensional bilateral tibial-fibular defects.


The authors described a case in which the dominant blood supply to a subperiosteally harvested serratus anterior muscle and rib composite myoosseous free flap came from the lateral thoracic artery. There were no other associated features in this patient to warn of the vascular variant. Reconstructive surgeons should be aware of possible variations in the vascular anatomy of this flap.


The authors reported a prospective assessment of pedicled extrathoracic muscle flaps for the closure of large intrathoracic airway defects after noncircumferential resection in situations in which an end-to-end reconstruction seemed risky (defects of less than 4 cm length, desmoplastic reactions after previous infection or radiochemotherapy). From 1996 to 2001, 13 intrathoracic muscle transpositions (6 latissimus dorsi and 7 serratus anterior muscle flaps) were performed to close defects of the intrathoracic airways after noncircumferential resection for tumor, large tracheoesophageal fistula, delayed tracheal injury, and bronchopleural fistula. In two patients, the extent of the tracheal defect required reinforcement of the reconstruction by use of a rib segment embedded into the muscle flap followed by temporary tracheal stenting. Patient follow-up was by clinical examination bronchoscopy and biopsy, pulmonary function tests, and dynamic virtual bronchoscopy by CT scan during inspiration and expiration. The airway defects ranged from 2 by 1 cm to 8 by 4 cm and involved up to 50% of the airway circumference. They were all successfully closed using muscle flaps with no mortality, and all patients were extubated within 24 hours. Bronchoscopy revealed epithelialization of the reconstructions without dehiscence, stenosis, or recurrence of fistulas. The flow-volume loop was preserved in all patients and dynamic virtual bronchoscopy revealed no significant difference in the endoluminal cross surface areas of the airway between inspiration and expiration above, at the site, and below the reconstruction. Intrathoracic airway defects of up to 50% of the circumference may be repaired using extrathoracic muscle flaps when an end-to-end reconstruction is not feasible.

The authors presented a case of a failed bipedicled (unilateral rectus flap with superior epigastric pedicle preserved and inferior epigastric vessels anastomosed to the thoracodorsal trunk as the second pedicle) transverse rectus abdominis muscle flap that had compromised the dominant pedicle of the latissimus dorsi muscle. A salvage procedure was possible using this muscle as a pedicle flap based on the backflow from the serratus anterior arterial branch with success. The use of the reconstructive ladder was highlighted.


The authors performed 77 procedures on 65 patients with large or medium-sized breasts, fulfilling the oncologic criteria for skin-sparing mastectomy. All operations were performed as a single-stage procedure, with an anatomic prosthesis inserted into a compound pouch formed from the pectoralis major, serratus anterior fascia, and a lower dermal adipose flap. The median size of the anatomic implants was 444.3 cc. The implant removal rate was 14.2%. At a median follow-up of 36 months, the authors reported a 0.3% local recurrence rate per year. The overall specific survival rate was 98.2%. This study confirmed the safety and effectiveness of this technical variation of skin and nipple-sparing mastectomies. All breast, irrespective of mammary shape and size, can be reconstructed with medium-sized implants and, if necessary, contralateral adjustments. The overall complication rate was in keeping with previous studies.


Reconstruction with the latissimus dorsi muscle flap, combined with the serratus anterior fascia flap, was performed to cover two large and separate palmar and dorsal forearm skin defects in a patient whose hand had been replanted 20 days earlier after traumatic amputation at the distal forearm level. As a result, a total forearm amputation was salvaged by microsurgical replantation and a free combined flap of the subscapular system. This new application of the combined flap allowed the reconstruction of large and separate wounds of the replanted hand and provided gliding surfaces for tendons.


The authors discussed a new field of application of the pedicled serratus anterior muscle flap. Severe axillary neuropathic pain and distress from neuroma formation were treated by wrapping the pedicled serratus anterior muscle flap around the brachial plexus. Covering the fascicles by well-vascularized muscle tissue results in significant postoperative pain relief. They described a new method in the treatment of severe neuropathic pain syndromes originating from the brachial plexus, with good result.


The serratus anterior flap is commonly used without its cutaneous component and is covered with a skin graft. The authors successfully used the free serratus anterior flap along with its skin paddle and found it to be valuable for reconstruction of the face. Fresh cadaveric dissections and arteriography were performed to identify perforator vessels to the skin overlying the muscle. Clinically, free transfer of the musculocutaneous flap to the face was carried out in 27 patients, mostly for severe noma (infection) sequelae. Anatomic dissection and arteriography revealed no cutaneous perforator vessels directly communicating with the vascular pedicle of the muscle. However, large perforators from the intercostal vessels were found passing through the muscle to reach the skin. In the clinical cases, flap survival was 100% in 24 patients.
Anterior Thorax

6D: Serratus Flap


The latissimus dorsi free flap is a workhorse for extremity reconstruction. One of its benefits is a long vascular pedicle that spans the zone of injury. However, it may be difficult to adequately cover this pedicle. Direct closure may be too tight, and skin grafting over the pedicle risks exposure if graft take is poor. We report a technique in which the serratus branch of the thoracodorsal artery and its overlying fascia are harvested en bloc with the thoracodorsal artery and latissimus muscle. This provides 2 flaps on a common pedicle that can easily be rotated to allow positioning and inset. We successfully used this technique in the reconstruction of both upper and lower extremities. The serratus fascia provides excellent padded covering and is a good bed for skin grafting. The versatility of this hybrid flap will allow its use in a range of complex reconstructive procedures.


Postmastectomy partial submuscular tissue expander placement can prevent the upper pole fullness commonly seen with complete submuscular prosthesis placement. The resultant inferior and lateral margins require coverage to prevent prosthesis exposure. The fascial layer overlying the serratus anterior muscle can be used as an alternative to previously defined techniques to provide composite lateral coverage. This method offers adequate coverage, prevents expander lateralization, and minimizes use of allogenic material. This study reported the anatomy, surgical procedure, clinical outcomes, and aesthetics following use of the serratus anterior fascial flap for lateral expander coverage in postmastectomy expander-based breast reconstruction. Twenty-two patients (31 breasts) who underwent breast reconstruction with serratus fascia were included in a retrospective case-note analysis after approval by the institutional review board. Demographics, perioperative factors, postoperative complications, patient satisfaction, and aesthetics were recorded as relevant endpoints. Ten fresh cadaver hemithoraces were dissected, and the serratus fascia for each was measured for length and width. At a mean follow-up of 197 days (range 71 to 370 days), seroma occurred in two breasts, wound infection occurred in one breast, partial mastectomy skin flap necrosis occurred in four breasts, and minor wound dehiscence occurred in one breast. There was no incidence of capsular contracture or hematoma. Four patients (five breasts) reported very mild tightness or banding in the lateral chest wall. The mean length of cadaver serratus fascia was 164.3 mm and the mean width was 122.8 mm.


In expander-based breast reconstruction, providing adequate tissue coverage of the prosthesis is necessary to prevent complications. The authors previously described the use of the serratus anterior fascia for this purpose, but when this fascia is unavailable or inadequate, the subpectoral fascia can be used. This study described the anatomy of the subpectoral fascia, the surgical technique for harvesting it, and an algorithm for choosing between the serratus and subpectoral fascia flaps. Clinical and functional outcomes following use of the subpectoral fascia in expander-based breast reconstruction were reported.


Postoperative empyema continues to present a complicated treatment scenario for thoracic and reconstructive surgeons. Muscle flaps are an important option in the management of complex thoracic wounds. This study was designed to report the Emory experience with muscle flaps for the management of complex postsurgical empyema. The authors also presented their treatment algorithm for managing empyema thoracis. They retrospectively reviewed the charts of 55 patients requiring different treatment modalities, including muscle flap transposition. Patients were divided into four groups according to the
initial thoracic procedure: no surgical resection; postpneumonectomy; postlobectomy; and prophylactic postpneumonectomy or postlobectomy. The study included 42 men (76.4%) and 13 women with a mean age of 62 years (range 39 to 77 years). Fifty-one muscle flap procedures were performed in 42 patients (serratus anterior flaps, 16 patients and 23 flaps; latissimus dorsi flaps, 16 patients and 18 flaps; pectoralis major muscle flaps, intercostal muscle flaps, and rectus abdominis flaps, three patients each: omental flap, one patient). The mean number of ribs resected before flap intervention, usually during the open window thoracostomy, was three. The average time from initial thoracic operation to flap intervention was 4 months. Average time from flap intervention to discharge was 12.5 days. Average hospital stay was 26.6 days. The 51 muscle flaps represented an average of 1.2 procedures per patient. The authors concluded that because of the excellent blood supply of extrathoracic muscle flaps and their ability to reach any place in the pleural cavity, they represent an ideal tissue with which to fill the contaminated pleural space.


In this study, combined fascial flaps pedicled on the thoracodorsal artery and vein were raised and used for thin coverage of dorsal surfaces of the fingers and the dorsum of hand and foot with favorable results. The combined flaps consisted of the serratus anterior fascia and the axillary fascia at the entrance of the latissimus dorsi. These flaps were used for reconstruction of the hand, fingers, wrist and palm, forearm, lower leg, or foot in nine patients. Reconstruction was performed for burn or burn scar contracture, after resection of malignant tumors, posttraumatic skin defects, and chronic regional pain syndrome. The flaps were used in various configurations, including two independent fascial flaps, two-lobed fascial flap with separate feeding vessels, and composite fascial and thoracodorsal artery perforator flap. The fascial and skin flaps survived in all nine patients, with favorable results both functionally and aesthetically. Good coverage of soft tissue defects and good recovery of range of motion in resurfaced joints were achieved. There were no complications. The scars at the sites of harvest were not noticeable.


The authors used autologous tissue for reconstruction of intrathoracic structures after extrapleural pneumonectomy in six patients. The resected areas of the hemidiaphragm and hemipericardium were reconstructed using combined reversed latissimus dorsi and serratus anterior muscle flaps. Based on their results, they concluded that the combined reversed latissimus dorsi and serratus anterior muscle flaps are broad enough to cover any defect within the hemithorax, and that this technique is the best choice for multisite reconstruction after extrapleural pneumonectomy.


Reconstruction of the dorsal surface of hand defects requires thin, pliable, well vascularized tissue with a gliding surface for the extensor tendon course. Also, defects of the palmar hand and degloved fingers need nonbulky soft tissue for reconstruction. The authors presented a retrospective analysis of nine patients with free serratus anterior fascia flaps used to cover defects of the palmar and dorsal hand and of degloved fingers. Three of the patients had limited range of hand motion from full-thickness burns; one patient had defects of the dorsum of one hand after an acute burn injury; two patients had an acute trauma of the dorsum of the hand with extensor tendon injury; one patient had a soft tissue defect of his thumb and dorsal hand from an avulsion injury; one had a dorsal defect of three fingers after degloving injury; and one had a palmar defect after an industrial crush injury with exposed tendons, vessels, and nerves. The flaps were applied as pure fascial flaps with an immediate partial-thickness skin graft. One patient developed partial necrosis of less than 10% of his flap. All other flaps survived completely. Two of the patients presented wound healing problems of the skin graft that healed secondarily. All patients recovered useful hand function without a bulky contour of their hand or fingers. Except for the scar, no donor-site morbidity was reported.

Complete degloving injury of three digits not amenable to revascularization may leave poor cosmetic and functional results. The authors used a compound thoracodorsal artery perforator (TDAP) flap in a 34-year-old, right-handed man with a traumatic degloving injury. The flap consisted of a thin, nonbulky skin component isolated on two perforators in combination with serratus fascia, both pedicled on the thoracodorsal vessels. The mobility of the two flap components allowed the palmar and dorsal part of the fingers to be reconstructed without relying on multiple flaps or anastomoses. The skin component of the TDAP flap was transferred to the palmar defect, the serratus fascia flap to the dorsal part of the fingers and sutured loosely. Coverage of the serratus anterior fascia was done with split-thickness skin graft. Both components of the flap survived completely. One month after the first operation, the surgical syndactyly between the middle and ring finger was separated, one month later the syndactyly between the ring and little finger. Good coverage of the soft tissue defects with good function could be achieved. There were no donor site problems.


Nine cases of massive soft tissue loss of the foot were reconstructed by means of a compound (chimera) thoracodorsal artery perforator (TDAP) flap, which reconstituted the different functional units (dorsum, heel, instep, weight-bearing surface). In each case, the flap consisted of a skin component isolated on its perforator in combination with a portion of latissimus dorsi muscle and/or serratus fascia, all pedicled on the thoracodorsal vessels. The pedicle length allows up to 4 to 6 cm of independent mobility of the skin island. The mobility of the various flap components allows the various functional units of the foot to be reconstructed without relying on multiple flaps or anastomoses. The pedicle length was sufficient to be able to perform the anastomosis out of the zone of injury. In some cases the skin island was harvested along with intercostal nerve branches, this provided the potential to develop a sensate flap.


Pleural space problems after lung resection and persistent air leaks are among the most common challenges posed to thoracic surgeons. Surgical repair of air leaks is indicated when conventional tube thoracostomy has failed to solve the problem. The authors proposed the novel application of the combined latissimus dorsi–serratus anterior transposition flap for selected cases of air leaks that are recalcitrant to conventional treatment. Five male patients between 32 and 70 years of age underwent the procedure between 2004 and 2007. Four patients had alveolar-pleural fistulas resulting in persistent air leaks; the fifth patient also had a space problem following lung volume reduction surgery. All patients had undergone prolonged treatment with chest drains without success. With the patient in a lateral decubitus position, a lazy-S incision was used to expose the entire latissimus dorsi and the proximal slips of the serratus anterior muscles. They were raised as pedicled flaps and transferred in tandem. The latissimus dorsi was introduced into the pleural cavity through a thoracic window and used to reinforce the fistula repair. The serratus anterior muscle closed the rib window. In all cases, the lungs reexpanded and chest drains were removed within 5 days after surgery. There were no recurrent air leaks at 1-year follow-up.
## ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>A flat, trapezoidal muscle on the superficial anterior chest wall. Related superiorly to the clavicle and deltoid muscle and inferiorly to the rectus abdominis and external oblique muscles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>23 × 15 cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>The clavicle, the sternum, and the fifth and sixth ribs.</td>
</tr>
<tr>
<td>Insertion</td>
<td>The lateral lip of the bicipital groove of the humerus.</td>
</tr>
<tr>
<td>Function</td>
<td>Adducts and medially rotates the arm.</td>
</tr>
<tr>
<td>Composition</td>
<td>Muscle, myocutaneous.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type IV.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Pectoral branch of thoracoacromial artery.</td>
</tr>
<tr>
<td>Minor Pedicles</td>
<td>Pectoral branch of lateral thoracic artery and internal mammary perforating arterial branches from first to sixth intercostal spaces.</td>
</tr>
</tbody>
</table>
Section 6E

ANTERIOR THORAX

Pectoralis Major Flap

CLINICAL APPLICATIONS

Regional Use
- Face
- Oral cavity
- Head and neck
- Anterior chest
- Sternum and mediastinum
- Axilla
- Upper extremity (shoulder)

Distant Use
- Head and neck
- Functional muscle

Specialized Use
- Mandible
- Esophagus
- Breast
- Functional muscle
ANATOMY OF THE PECTORALIS MAJOR FLAP

Dominant pedicle: Pectoral branch of thoracoacromial artery
Minor pedicles: Perforating branches of internal mammary artery
ANATOMY

Landmarks  A flat, trapezoidal muscle on the superficial anterior chest wall. It is related superiorly to the clavicle and deltoid muscle and inferiorly to the rectus abdominis and external oblique muscles. Deep to it lie the pectoralis minor, serratus anterior, intercostal muscles, and ribs.

Composition  Muscle, myocutaneous.

Size  Muscle: 23 cm long × 15 cm wide; skin: 6 × 12 cm.

Origin  The medial half of the clavicle, the anterior surface of the sternum, the fifth and sixth ribs, and the aponeurosis of the external oblique muscle

Insertion  The muscle fibers converge toward the axilla, and the tendon inserts into the lateral lip of the bicipital groove of the humerus.

Function  The pectoralis major adducts and medially rotates the arm.

Arterial Anatomy (Type IV)

The thoracoacromial pedicle enters the muscle on its deep surface at approximately the junction of the middle and lateral third of the clavicle. The perforating branches of the internal mammary artery enter on the deep surface in each intercostal space approximately 1.5 to 2 cm from the sternal edge. They vary in size from space to space; however, the pedicle in the second interspace is consistently larger than the others.

Dominant Pedicle  Pectoral branch of thoracoacromial

Regional Source  Subclavian artery.

Length  4 cm.

Diameter  2 to 2.5 mm.

Location  Emerges below the clavicle and enters the deep surface of the upper border of the muscle approximately at the junction of the middle and lateral third of the clavicle.

Minor Pedicle  Pectoral branch of lateral thoracic artery

Regional Source  Subclavian artery.

Length  3 to 4 cm.

Diameter  1 to 2 mm.

Location  Emerges below the clavicle and enters the deep surface of the upper border of the muscle 3 or 4 cm lateral to the thoracoacromial branches.

Minor Segmental Pedicle  Internal mammary perforating arterial branches through first to sixth intercostal spaces

Venous Anatomy

Single veins accompanying the arterial circulation; the average venous diameter is 1 to 2 mm.
Nerve Supply

Motor  
The lateral or superior pectoral nerve originates from the lateral cord of the brachial plexus and is located lateral to the axillary artery. It enters the muscle on its deep surface in close proximity to the dominant vascular pedicle. It innervates the clavicular and anteromedial portions of the sternal heads of the muscle. The medial or inferior pectoral nerve originates from the medial cord of the brachial plexus and lies medial to the axillary artery. It passes between the axillary artery and vein to enter the pectoralis minor muscle on its deep surface. It supplies the pectoralis minor muscle, and then two or three branches pass into the pectoralis major to supply the posterolateral portions of the muscle.

Sensory  
The second through seventh intercostal nerves provide segmental sensory innervation to the overlying skin.

Vascular Anatomy of the Pectoralis Major Flap

Deep surface of right-sided pectoralis major flap

Closeup view of flap base

Fig. 6E-2

Dominant pedicle: Pectoral branch of thoracoacromial artery (D)
**Deep surface of right reverse (turnover) flap demonstrating segmental mammary perforating vessels**

**Deep surface of flap**

**Radiographic view**

**Fig. 6E-2**

**Dominant pedicle:** Pectoral branch of thoracoacromial artery (D)

**Minor pedicles:** Perforating branches of internal mammary artery (s)
**FLAP HARVEST**

**Design and Markings for Standard Muscle Flap**

The cutaneous territory of the pectoralis major lies between the parasternal line and the anterior axillary line and extends from the clavicle to the sixth intercostal space.

The clavicle marks the upper border of the muscle and the sternum its medial border, extending down to the seventh rib. The anterior axillary fold marks the anterolateral border. It is useful to outline these landmarks preoperatively in a standing patient. All or portions of the muscle and the overlying skin may be included, depending on the design of the flap and the requirements of the defect.

The entire overlying skin on the muscle or smaller islands of skin may be elevated. A variety of skin islands have been designed on the pectoralis major. The exact design, size, shape, and position of the skin island will vary with the requirements of the defect. For head and neck reconstruction in women, the breast can interfere with flap design. The skin island is located below the breast at or just above the inframammary crease to maintain aesthetics and not carry breast tissue into the reconstruction. In men, the skin island is located anywhere over the muscle and is usually vertically oriented.

In certain situations, the skin island should be designed and the flap elevated with preservation of the deltopectoral flap for possible later use in head and neck reconstruction. However, aesthetic considerations can prevail and dictate avoiding vertical scars and using a horizontal skin island design.

*Fig. 6E-3* Skin island designs for head and neck coverage. **A**, 1: a. For access to muscle for reverse flap based on the mammary perforating vessels. b. Access incisions for muscle-only harvest for head and neck reconstruction, leaving the deltopectoral flap available for future use. c. Deltopectoral incision to release the muscle origin for use with a and possibly b. 2: Typical vertical skin design used in men. **B**, 1: Access incisions for muscle-only harvest for head and neck reconstruction, sparing the breast and leaving the deltopectoral flap available for future use. 2: Typical skin design in women to avoid taking breast tissue with the flap and to minimize donor site deformity.
For sternotomy wounds, turnover and advancement flaps are usually exposed through the midline incision or the existing wound. Occasionally, a counterincision in the deltopectoral groove is required for muscle release. Ideally, the skin island design should not extend below the inferior border of the pectoralis major muscle, because its blood supply then becomes increasingly random. Flap delay should be considered if more flap is needed.

**Patient Positioning**
The patient is positioned in the supine position for both flap harvest and inset.

**GUIDE TO FLAP DISSECTION**

**Standard Muscle Flap**
The muscle can be dissected from an overlying incision, midline scar, or wound. The overlying skin is dissected off the muscle, and the entire superficial surface of the muscle is exposed. Submuscular dissection is facilitated by use of a lighted mammary retractor.

When a head and neck flap is planned, the lateral free border of the pectoralis major is elevated to expose the underlying pectoralis minor muscle, and the muscle is divided laterally to release it from its humeral insertion.

The thoracoacromial pedicle is visualized on the deep surface of the muscle located laterally at the junction of the medial two thirds and lateral third of the clavicle and is spared. The segmental perforating branches from the internal mammary artery are visualized within 5 to 6 cm of the midline and are left in situ in case a deltopectoral flap is required later. The medial muscle is divided lateral to these mammary perforators, and the muscle division is tapered proximally to the thoracoacromial pedicle to improve rotation.

![Fig. 6E-4](image-url)

**Fig. 6E-4**  A, Typical access incisions for muscle only harvest in a, men and b, women. B, Initial dissection to expose the anterior surface of the muscle.
FLAP VARIANTS

- Myocutaneous advancement flap
- Muscle advancement (slide)
- Reverse (turnover) flap
- Vascularized bone
- Functional muscle flap
- Tissue expansion

Myocutaneous Advancement Flap

The myocutaneous flap is based on the thoracoacromial blood supply. Only a central strip of muscle carrying the vascular pedicle needs to be harvested, unless muscle is also required for the reconstruction. The skin island is incised around its periphery, and dissection is taken down to the muscle fascia. The intervening skin between the clavicle and the proximal end of the harvested skin island is elevated to expose the underlying pectoralis major muscle belly. With a Doppler probe the exact location of the thoracoacromial vessels can be identified, although they consistently lie at the junction of the mid and lateral thirds of the clavicle. The distal end of the muscle underneath the skin island is elevated from the chest wall and the
subpectoral plane is entered. Gentle submuscular finger dissection frees it up in a cephalad direction, allowing insertion of a lighted fiberoptic retractor to visualize the thoracoacromial vessels beneath the muscle. A suitable narrow strip of muscle containing the pedicle is then incised with cautery from either side of the skin island up to the clavicle, taking care to protect the pedicle. The narrower the muscle segment at the clavicle, the easier the flap rotation. The flap is then delivered through the infraclavicular incision in preparation for tunneling or directly transposing the flap up into the neck, face, or oral cavity.

**Muscle Advancement (Slide)**

If the flap is to be used as an advancement muscle flap for central defects based on the thoracoacromial pedicle, the origin is divided through the dissection field with division of mammary perforators. The thoracoacromial pedicle is visualized on the undersurface of the muscle, and the muscle is advanced centrally, either unilaterally or bilaterally. If more muscle advancement is required, the insertion of the muscle can be divided lateral to the thoracoacromial pedicle, either unilaterally or bilaterally. This technique may not cover lower sternal wounds well (see Reverse flap).

**Fig. 6E-5**  
A, Bilateral pectoralis major flaps for a central sternal defect. The muscle has been released at its origin along the sternum and laterally at its insertion through separate skin incisions. This can sometimes be accomplished through the wound. B, Both muscles have been advanced centrally to reconstruct the defect.
Reverse (Turnover) Flap

**Sternal Coverage**

Better coverage of the sternum can sometimes be obtained by using the muscle based on its internal mammary supply. This significantly reduces blood flow to the overlying skin, rendering it more susceptible to marginal necrosis at the midline. Once the muscle is exposed, the distal insertion to the humerus is cut within the anterior axillary line. This results in loss of the anterior axillary fold’s definition, unless the distal pectoral stump from the humeral insertion is sutured to the more medial pectoralis minor muscle belly. An alternative approach is to make an L-shaped cut in the distal muscle, leaving a thin caudal strip still attached to the chest wall. This preserves the anterior axillary fold contour. The superior border of the muscle is then freed off the clavicle as the distal cut end is turned over and retracted medially to expose the undersurface of the pectoralis major. The surgeon will encounter the thoracoacromial vessels at the junction of the lateral and middle thirds of the muscle just below the clavicle. These vessels should be securely suture-ligated or clipped, because they are sizable. Once the muscle is fully delivered into the mediastinal wound, its undersurface is superficial and the medial internal mammary perforators are clearly visible between the costal cartilages.

**Fig. 6E-6**

A. An L-shaped incision is made in the pectoralis major muscle insertion to maintain the anterior axillary fold; the thoracoacromial vessels are identified and cut on the deep surface of the flap. B. The muscle is turned over to expose the divided thoracoacromial vessels. C. The pectoralis major is split into a smaller upper flap and a larger lower flap, each based on the internal mammary perforator; the lower flap is positioned inferiorly and the upper flap superiorly.
Because this turnover flap has a segmental blood supply, it may be split into two or three separate medially based flaps. The muscle is split in the direction of the fibers, laterally to medially. This allows an improved arc of rotation for these turnover flaps to provide complete sternal coverage and is particularly useful for enabling some muscle to reach the problematic inferior portion of the sternal wound.

**Vascularized Bone**

Vascular communications are present between the fibers of the muscle and the periosteum of the fifth and sixth ribs at its costal origins, permitting transposition of the pectoralis muscle with rib. This vascularized flap will reach intraoral defects and may be used for mandibular reconstruction. A portion of the sternum may also be elevated with this flap as vascularized bone.

The rib is divided at the costochondral junction. The intercostal muscles are then divided and the rib mobilized off the underlying pleura. Dissection or injury to the periosteum must be avoided. When a sufficient length of rib has been mobilized, the rib is divided laterally and the rest of the dissection continues as described for standard flap elevation. In a similar fashion, the outer table of the sternum may be mobilized with the fibers of origin of the pectoralis.

![Fig. 6E-7 Vascularized bone territory.](image_url)
Functional Muscle Flap
The pectoralis major is a tertiary choice for functional transfer. Based on the dominant thoracoacromial pedicle and lateral (superior) pectoral nerve, it may be transferred to the upper arm for elbow flexion.

The pectoralis is a useful functional muscle transfer for elbow flexion. The incision is made along the anterior axillary line; through that incision the pectoralis is visualized and the skin and subcutaneous tissue are dissected off the muscle for complete muscle exposure. An innervated portion of the muscle is then outlined. The origin is taken down and the muscle mobilized from its origin toward its insertion, preserving the thoracoacromial blood supply and the motor nerves. The muscle is tunneled through the axilla onto the upper extremity and sutured to the biceps tendon while stretched to an appropriate tension.

Tissue Expansion
Preliminary expansion of the adjacent skin or the muscle may be helpful in enlarging the flap or minimizing the donor defect. Expansion is helpful and often necessary for the placement of submuscular implants in breast reconstruction. However, the usual transpositions of the flap do not require prior expansion.

ARC OF ROTATION
Muscle and Myocutaneous Flap
Head and Neck
Based on the single dominant thoracoacromial pedicle, the muscle will provide coverage for the head and neck up to the level of the inferior orbital rim. Division of the muscle is required at both origin and insertion, taking care to preserve the thoracoacromial pedicle. Tapering the muscle division near the pedicle improves the flap’s arc of rotation. Extension of the skin paddle will increase the arc of rotation, but a delay procedure may be required.

Fig. 6E-8
Intrathoracic Cavity
An island pectoralis muscle flap based on the dominant thoracoacromial pedicle will provide intrathoracic filling for the upper part of the thoracic cavity. To place the muscle into the intrathoracic cavity, portions of the second, third, or fourth ribs closest to the pedicle are resected to allow the island muscle flap to be placed in the chest cavity.

Sternum
A standard island pectoralis flap based on the thoracoacromial vessels will easily advance to cover anterior chest defects and provide sternal fill.
Reverse Flap
The turnover flap based on the minor segmental pedicles is used predominantly for coverage of the sternum and mediastinum and easily reaches across the midline. This modified flap will preserve the anterior axillary fold.

FLAP TRANSFER
Head and Neck
Once the flap is isolated on the thoracoacromial pedicle, the flap is transferred to the head and neck by direct transposition or subcutaneous tunnel. Care must be taken to ensure that there is no tension or compression on the pedicle.

Sternum
Both direct and reverse flaps are directly transposed into the sternal defect. When possible, sternal fill is provided by advancing the muscles fully into the defect. One must be careful to cover the inferiormost part of the wound, because this is the area of highest failure.

Intrathoracic
A window in the thorax created by rib and muscle removal allows the muscle to be directly transposed into the chest. The window should be located near the pedicle origin.

FLAP INSET
For head and neck reconstruction, the muscle and the skin island are sutured into the defect without tension. For sternal coverage, the muscle is sutured into the sternal wound over suction drains. Given the tendency of muscle to tear when sutured, it is helpful to use 2-0 or 3-0 Vicryl horizontal mattress sutures to minimize muscle fraying. The muscle can be stabilized for intrathoracic use by sutures at the entry to the chest as well as intrathoracic tacking sutures or fibrin glue.

DONOR SITE CLOSURE
The donor defect is usually closed directly for small skin islands. Larger skin islands require a skin graft or a secondary flap to close the donor area. The donor site can be closed directly for sternal wound coverage by wide skin undermining. When rib is harvested with overlying skin, an abdominal flap is preferable for closure of the donor defect if direct closure is not possible.
CLINICAL APPLICATIONS
This patient developed suppurative mediastinitis. She underwent debridement of the sternum back to healthy, bleeding bone. The pectoralis major muscles were elevated as bilateral myocutaneous advancement flaps. No release of the muscle insertion was required. The muscles were approximated in the midline with overlying skin repair bolstered with retention sutures. The patient healed without physical deformity and no recurrence of sternal wound sepsis.

Fig. 6E-12 A, The patient is seen before flap reconstruction, 10 days after CABG surgery, with an inflamed, draining sternal wound. B, A bilateral partial sternectomy was performed. C, Medial edge of left pectoralis major myocutaneous advancement flap. Note that the skin is separated only 2 cm from the muscle edge. D, Flap shown at the level of the subpectoral plane. E, Completed closure with well-vascularized skin edges. (Case supplied by G.J.)
This patient underwent a four-vessel coronary bypass procedure, complicated by hematoma requiring reexploration. A methicillin-resistant *Staphylococcus aureus* (MRSA) deep sternal wound infection supervened, necessitating debridement and flap closure. The wound was excised with a partial hemisternectomy on the right and a complete hemisternectomy on the left. The wound was closed with a left pectoral advancement flap based on the thoracoacromial vessels and a right pectoral turnover based on the right internal mammary vessels. The patient healed well, although with some hollowing at the site of the turnover flap donor site.

**Fig. 6E-13**  
A, Debrided sternum with exposed pericardial sac.  
B, Left pectoralis major muscle exposed for advancement.  
C, Right split turnover flap exposed.  
D, Right split turnover flap based on internal mammary perforator, and left advancement flap based on the thoracoacromial artery.  
E, The three flaps are interlocked, with the left advancement flap spliced between the two components of the right turnover flap. (Case supplied by G.J.)
This patient had a sarcoma of the right anterior chest wall. The tumor was resected and polypropylene mesh was placed to repair the chest wall. The resection site was covered with a pectoralis major transposition flap covered with a split skin graft. The patient is shown well healed at 6 months postoperatively.

Fig. 6E-14  A, Recurrent malignant fibrosarcoma of the chest with a previous thoracotomy, midline laparotomy scar, and bilateral subcostal incisions. B, Resection of skin, tumor, ribs, and pleura covered with a double layer of Prolene mesh. C, Longitudinal incision to expose the pectoralis major muscle. D, Turnover of the pectoralis major based on internal mammary perforators showing a divided thoracoacromial pedicle. E, Healed skin grafted muscle flap. (Case supplied by G.J.)
This 30-year-old man had a sarcoma resected from the right clavicular area. He underwent reconstruction with a mycutaneous pectoralis major flap based on the thoracoacromial pedicle.

Fig. 6E-15  A, The sizable defect and the plan for a vertically designed mycutaneous flap are shown. It is important to keep the skin paddle directly over the pectoralis major muscle to prevent necrosis. Larger paddles can be designed but should be delayed to ensure vascularity. B, The flap was elevated, narrowing the muscle at the level of the pedicle to facilitate rotation. C, The flap was inset with care taken to avoid a tight subcutaneous tunnel and kinking of the pedicle. Primary closure was attained at the cost of nipple migration. D, At 2-month follow-up, the patient is seen with uncomplicated healing. (Case supplied by MRZ.)
This 52-year-old woman had a failed fibular free flap after composite resection of a squamous cell carcinoma. After removal of the flap, the mandibular reconstruction plate was salvaged with a pectoralis major muscle flap.

Fig. 6E-16  A, The muscle was isolated on its thoracoacromial pedicle, accessed through inframammary and subclavicular incisions. The Xs mark the mammary perforators that were left in situ, preserving the option of a deltopectoral flap. The muscle is quite narrow at the level of the clavicle to facilitate rotation and reach to the plate. B, The thoracoacromial pedicle is visible. The muscle easily reached the plate and wrapped it completely. C, The noncompliant irradiated neck skin would not close over the muscle without excessive tension, so a skin graft was placed. Intraoral closure was obtained in part with mucosa and part by remucosalization of exposed intraoral muscle. D, Her donor scars at 4 months postoperatively are well hidden. E, Although the flap, skin, and intraoral closure all healed without incident, she was left with a contracture band of pectoralis muscle and contracted skin graft. She was a candidate for a deltopectoral flap because of the method of pectoralis harvest (see Section 6A, Deltopectoral Flap). (Case supplied by MRZ.)
Pearls and Pitfalls

- The pectoralis major is not entirely dispensable, and some functional disability may result from its use.
- Mobilization of the entire muscle as a standard flap with division of the insertion will result in the loss of the anterior axillary fold, causing a significant aesthetic deformity.
- Flap modifications that preserve the anterior axillary fold may also preserve some muscle function.
- The vascularized bone included with the flap may not always be reliable.
- Problems associated with the pectoralis major muscle include the bulk of the flap over the clavicle and in the intraoral area, as well as the donor area deformity.
- Performing muscle turnover and advancement flaps requires elevating the chest wall skin, which predisposes it to necrosis of the skin edges.
- Subpectoral donor sites should be drained aggressively for a long time to reduce seroma formation.
- To create a tubed pectoralis myocutaneous flap for esophageal reconstruction, a large skin island is designed on the pectoralis and the muscle and skin elevated. The flap is tubed so that the skin surface is on the inside, representing the lumen of the neoesophagus. The flap is then sutured into the esophageal defect, and a skin graft is required for coverage of the outer muscular surface of the tubed flap.

EXPERT COMMENTARY
Glyn Jones

Indications
The pectoralis major remains one of the most versatile flaps for mediastinal reconstruction. Its robust blood supply and its ability to be advanced on the thoracoacromial supply or turned over on the internal mammary supply make it invaluable for treating wounds resulting from suppurative mediastinitis. It can also be swung down onto anterior chest wall defects after tumor resection.

With pedicles on the thoracoacromial vessels, it can be tunneled beneath the neck skin to reach the floor of the mouth, mandible, and chin. It has proved itself as a workhorse flap in head and neck reconstruction.

Advantages and Limitations
Recent modifications to the way in which the flap is raised have reduced donor site morbidity as well as skin edge necrosis. When it is used as a turnover flap, the overlying skin is significantly devascularized, resulting in a higher risk of skin edge necrosis when used to reconstruct mediastinal wounds. The use of a composite myocutaneous design, leaving the skin attached to the muscle, dramatically improves the cutaneous blood flow and reliability of this flap. Its use in the head and neck is limited by its arc of rotation to floor of the mouth and mandibular defects only. Although it can reach the base of the ear, tension on the flap can be problematic.
Personal Experience and Insights

The use of pectoralis major myocutaneous flap advancement dramatically improved both operative time and reduced donor site morbidity in my management of suppurative mediastinitis following coronary artery bypass procedures. Although the advancement flaps do not completely fill the underlying dead space as effectively as a turnover and island advancement had done previously, effective suction drainage beneath the flaps can be shown to collapse the dead space when viewed on CT scans. When the flap is used in head and neck surgery, volume in the neck can be reduced by raising only a strip of muscle over the proximal pedicle, expanding this to incorporate a larger skin island inframedial to the nipple for use within the recipient site.

Recommendations

Planning

For mediastinal use, the entire flap is advanced from its sternal origin into the wound. Use in the head and neck requires a narrow base to reduce bulk within the subcutaneous tunnel in the neck, with a large skin paddle and a broader sheet of muscle for intraoral placement. In men, a skin island is usually designed from the level of the fourth costal cartilage to below the nipple, and about 20% of the skin can be harvested beyond the inferior most limit of the muscle origin. In women, it is preferable to try and use skin medial to and below the breast, but great care has to be taken not to outrun the blood supply.

Technique

When using the flap as a myocutaneous advancement for sternal closure, I do not divide the insertion into the humerus, which preserves the anterior axillary fold. The medial skin edge is elevated for only 1 cm off the cut edge of the muscle’s origin from the sternum, and this usually allows very adequate medialization of the flap to the midline. Great care should be taken to ensure excellent control of internal mammary perforators before closure. For head and neck reconstruction, subpectoral dissection is carried up along the access of the thoracoacromial vessels to the clavicle, and under direct vision, a thin strip of muscle on either side of this can be preserved for several centimeters before extending the muscle harvest to supply the distal skin island. This dramatically reduces bulk in the neck and again preserves the anterior axillary fold. The pedicle must not be twisted when the flap is tunneled into the facial recipient site.

Postoperative Care

Long-term suction drainage is essential after myocutaneous advancement into the mediastinum. Patients undergoing head and neck reconstruction with pectoralis major flaps should be nursed with the neck slightly extended and not flexed for fear of kinking the blood supply. Similarly, patients with tracheostomies should have their tracheostomy tapes tied loosely around the neck to prevent compression. Feeding tubes should be used until intraoral suture lines are well healed.

Complications: Avoidance and Treatment

Myocutaneous advancement flaps have a significant risk of submuscular seroma formation. The bed of the donor site should be sprayed with fibrin glue, and subpectoral drains should be inserted and maintained until drainage is less than 30 ml per drain per day. If long-term drainage becomes problematic, installation of steroids or doxycycline can be helpful. Mediastinal skin edge necrosis can be reduced dramatically by maintaining the...
relationship between the muscle and the overlying skin as a composite myocutaneous flap. The more the skin is elevated from its underlying muscle-based blood supply, the more likely it is to necrose. In head and neck reconstruction, the rotation from chest to neck must be performed under direct vision to ensure that the vascular pedicle is not twisted or alternatively kinked over the clavicle. If a turnover flap into the mediastinum does have to be performed, the supralateral slips of the muscle should be left attached between chest wall and humerus to preserve the axilla fold. Loss of this fold, particularly in men, creates a very unattractive deformity.

Bibliography With Key Annotations

Anatomic/Experimental Studies


This experimental study demonstrated that the pectoral muscle wrapped around the heart revascularized the myocardium with establishment of circulation through the muscle flap into the myocardium in 12 dogs.


The authors reported the results of their anatomic dissections of 17 cadaver specimens to delineate the vascular anatomy of the pectoralis major and the overlying skin. They described a rich anastomosis between the internal mammary artery and the pectoral branch of the thoracoacromial artery and the pectoral branch of the lateral thoracic artery. They concluded that the lateral thoracic artery, in addition to the pectoral branch of the thoracoacromial artery, contributed significantly to the vascularity of the pectoralis major and was the main blood supply of the female breast.


In this study the authors analyzed the anatomic basis for the use of the pectoralis major muscle based on alternative pedicles to evaluate its clinical applications in cases of potential impairment of more distal internal mammary artery. The patterns of blood supply depending on the internal mammary artery, previously dissected for coronary bypass surgery, were studied in both sides of five embalmed cadavers and five anterior thoracic walls taken from autopsies. The secondary vascular pedicles, depending on the internal thoracic artery for the pectoralis major muscle, were dissected and injected with physiological saline–stained solution in the embalmed cadavers. Studies of intravascular injection by means of radiopaque contrast and physiologic saline–stained solution were carried out in the anterior thoracic walls in autopsy specimens. The results showed that complete injection of the pectoralis major muscle was achieved based exclusively on the two proximal perforating branches of the two first intercostal spaces, in cases with previous dissection of the internal mammary artery for coronary bypass. This may represent collateral flow from the anterior branches of the intercostal arteries.


Anatomic studies, animal studies, and clinical experience demonstrated splitting of the pectoralis major muscle and myocutaneous units based on the thoracoacromial pedicle. Three major independent segments (clavicular, sternocostal, and external) were identified and demonstrated. Segmental splitting techniques allow utilization of the muscle as a flap while preserving form and function.

This is a detailed anatomic study of the acromiothoracic trunk and its four main branches. The distribution of these vessels was described in detail, and the authors’ experience with 52 pectoralis major myocutaneous flaps for head and neck reconstruction was presented.

Clinical Series


This is the original description of the pectoralis major myocutaneous flap for head and neck reconstruction. A narrow strip of the pectoralis major muscle based on the thoracoacromial pedicle together with an overlying island of skin was used successfully in four patients.


Reconstruction of difficult wounds in 20 patients was described, including reconstruction of orbital and pharyngoesophageal defects.


The authors reviewed their experience with 133 pectoralis major myocutaneous flaps for head and neck reconstruction. Of the 133 flaps used, 11 flaps (8%) failed to accomplish the intended purpose and a second operation was necessary. Of the five patients who underwent reconstruction with the osteomyocutaneous flap, three were treatment failures. This is an important article with an excellent review and analysis of results.


The authors described their technique and experience with 14 hypopharyngeal and cervical esophageal reconstructions using the flap. All flaps survived, but three patients developed suture line separations.


Bilateral island pectoralis major flaps are used for reconstruction of a full-thickness anterior chest wall defect. The flaps are based on the dominant thoracoacromial artery and covered with split-thickness skin graft.


This paper reported on the use of pectoralis major flap usage to treat deep sternal wound infections in neonates. Seven hundred twenty consecutive pediatric cardiac operations performed in 108 neonates and 612 infants were reviewed. Six neonates and 3 infants developed deep sternotomy wound infections and underwent PMF reconstruction. The incidence of sternal wound complications in the neonatal patients (5.5%; 6 of 108) was significantly higher than in the infantile group (0.5%; 3 of 612). Five neonates were treated with a unilateral, turnover PMF reconstruction. One patient was treated by a bilateral rotational PMF. All sternal wounds healed successfully, and all patients survived. In a follow-up period ranging from 6 to 31 months (mean 16.5 months), the growth and development of all operated neonates was as expected for their age. There were no signs of chronic sternal infection. Early recognition of sternal wound complications and treatment utilizing the PMF resulted in early stable wound closure with no long-term growth implications.


Three cases of axillary reconstruction with the pectoralis major myocutaneous island flap were reported. The authors suggested this flap as an alternative if the latissimus dorsi is not available.

The authors assessed the utility of the pectoralis major muscle flap (PMMF) in patients undergoing salvage total laryngectomy in a retrospective analysis of 461 patients who underwent laryngectomy. Eighty of them underwent salvage surgery with primary pharyngeal closure; 69 (86%) underwent primary pharyngeal closure alone and 11 (14%) underwent a PMMF to buttress the pharyngeal suture line. Two hundred thirty-six variables were recorded for each patient. Complications related to pharyngeal closure were measured. Sixty-four percent of the patients who underwent PMMF also underwent chemoradiation therapy as the initial definitive treatment, compared with 25% in the non-PMMF group. Multivariate analysis demonstrated that chemoradiation therapy was the only independent predictor of pharyngocutaneous fistula formation (relative risk, 1.82; 27%) and the non-PMMF (24%) groups. Furthermore, similar durations of tube feeding, days to oral feeding, and hospitalization period were recorded in both groups, leading the authors to conclude that the PMMF should be used judiciously as a surgical adjunct in high-risk patients to minimize the risk of a pharyngocutaneous fistula.


This is the original description of the pectoralis myocutaneous flap as a delayed procedure to reconstruct a full-thickness defect of the anterior chest wall following the resection of a fibrosarcoma.


This landmark paper represented a paradigm shift in thinking about the management of sternal wound infection. Rather than performing total sternectomy, the authors debrided back to healthy bleeding bone. Instead of filling the defect with muscle, the authors used bilateral pectoralis major advancement myocutaneous flaps for closure, resulting in less skin edge of the chest.


The authors presented the Emory University experience with sternal wound closure using a variety of muscle flaps, most commonly the pectoralis major advancement-turnover combination in treating 409 patients. Mortality was reduced and hospital stay declined from 18 days to 12 days using these techniques. Pectoral flaps had a much lower morbidity than did rectus abdominis flaps for the treatment of deep sternal wound infections. The authors subsequently moved to using bilateral pectoralis major advancement myocutaneous flaps for closure rather than the turnover-advancement combination.


The use of bilateral pectoralis major omental or rectus abdominis muscle flaps for the treatment of the infected median sternotomy wound was presented. A dramatic decrease in the mortality and morbidity associated with infected median sternotomy wounds was documented and attributed to the use of muscle flaps.


In this case report the author predicted that the pectoralis major myocutaneous flap will eventually replace the deltopectoral flap as the preferred flap for head and neck reconstruction. He also suggested modification of the incision below the clavicle to preserve the ipsilateral deltopectoral flap for future use.


This paper evaluated shoulder function in 22 patients who underwent PMF reconstruction. The control group comprised 35 patients with neck dissection (without PMF). The data suggested that much of the morbidity after head and neck procedures with neck dissection arises from the neck dissection. There is minimal or low shoulder morbidity caused by PMF reconstruction in head and neck surgery.
Anterior Thorax • 6E: Pectoralis Major Flap


The authors review their experience with a total of 506 pectoralis major flaps used for head and neck reconstruction in 500 patients. In all cases the flap was used after surgical resection of an advanced malignant tumour of the head and neck. The tumours were intraoral in 387 cases (77%), pharyngeal in 78 cases (15%) and on the skin in 10 cases (5%). The defect was located in the mucosal lining in 407 (81%), skin in 43 (8%), both intraoral and extraoral in 53 (10%) patients. Bone defects occurred in 65 patients. In 31 patients (6%), the pectoralis major flap was used in combination with other flaps (deltopectoral, tongue, trapezius, and free flaps). Complications occurred with 168 flaps (33%), but total flap necrosis was seen in only 10 patients (2%). Surgical treatment of complications was necessary in 87 patients (17%). They conclude that despite the increasing use of microvascular reconstruction, the pectoralis major myocutaneous flap continues to be the most reliable major flap in head and neck reconstruction with acceptably low complication rates.


A review of 211 patients who had undergone muscle flap closure of infected median sternotomy wounds is described. When compared to closed irrigation and open granulation techniques, flap closure was shown to result in a fourfold decrease in mortality and significantly decreased length of hospitalization following treatment. The authors concluded that debridement and flap closure is the primary therapy for patients with poststernotomy mediastinitis.


The authors described their experience with five patients undergoing laryngopharyngectomies and cervical esophagectomies who underwent reconstruction with tubed pectoralis major flaps. Two patients had pinpoint fistulas that healed rapidly. One patient died of myocardial infarction, and the fifth patient had a partial flap breakdown requiring secondary flap closure. Despite this high complication rate the authors advocate the tubed pectoralis major flap for total esophageal reconstruction and they recommend this method over colon interposition, gastric pull-through, or even jejunal free grafts.


The authors reviewed their experience with 25 patients who had undergone major head and neck resections for stage III and IV carcinoma, all of whom required hypopharyngeal reconstruction with the pectoralis myocutaneous flap. Only six patients were alive 1 year after reconstruction, and five were available for study. Postoperative strictures were found in two patients.


Nine patients who had postoperative pharyngocutaneous fistulas underwent one-stage correction using a variety of flaps. These included four pectoralis major, two latissimus dorsi, and three jejunal free grafts. The indications for each flap were clearly discussed.


The author reviewed his experience with six patients who underwent mandibular reconstruction using a pectoralis major osteomyocutaneous flap including rib and 22 patients undergoing similar reconstruction with an osteomyocutaneous flap including the sternum. Five of 6 patients in the rib group had major complications. Loss of bone occurred in only 2 of 22 patients in the sternum group. The author stated that an osteomyocutaneous pectoralis major flap with sternum is more reliable and results in more functional and aesthetic reconstructions.

Case reports of the use of a pectoralis major myocutaneous flap for coverage of an extensive area of radioencephal over the shoulder were presented.


This case report described the use of the tubed pectoralis myocutaneous flap for one-stage reconstruction of the pharynx and esophagus.


This study compared the tongue function outcome in Mandarin-speaking patients obtained using two methods of tongue reconstruction, radial forearm free flap transfer and pectoralis major flap transfer. Twenty-five patients with carcinoma of the tongue underwent tumor resection with reconstruction using a pectoralis major flap in 6 patients and a radial forearm flap in 19 patients. Swallowing and speech function were evaluated 6 months to 5 years after the reconstruction. Speech intelligibility and a Mandarin articulation test were used to evaluate the articulation proficiency before and after surgery. Clinical evaluation of deglutition included a questionnaire on dietary habits and a swallowing rating of 1 to 7. Patients with free flap reconstruction had more intelligible speech (p = 0.014) even after total glossectomy. Assessment of data obtained by clinical questionnaire showed no significant difference between the two groups in swallowing function. Motility from flap pliability increased speech intelligibility but had little effect on swallowing function. The results suggest that radial forearm flap transfer is better than pectoralis major flap transfer in preserving speech function, but there is no significant difference between the two methods of reconstruction in their impact on swallowing function.


The authors described their experience with the pectoralis major myocutaneous unit in single-stage reconstruction of the pharyngoesophageal region in seven patients. All reconstructions were successful, with one patient experiencing salivary leak temporarily. Most of their patients were able to swallow within 9 to 10 days. The advantages of the flap include predictable anatomy, long arc of rotation, one-stage reconstruction, and viable muscle to protect the carotid vessels. The disadvantages are the scarring of the chest wall and distortion and dysfunction of the pectoralis major because of the procedure and a prominent bulge in the neck because of the pedicle.


The authors described their experience with the flap for immediate pharyngeal reconstruction in nine patients. In two patients the flap was used for total hypopharyngeal reconstruction and in the remainder for partial reconstruction. They reported a high success rate with minimal complications.

Flap Modifications


The authors described their experience with 14 mandibular reconstructions using the pectoralis major osteomyocutaneous flap incorporating the fifth or sixth rib. One of the 14 flaps was lost, and the rib was removed in three others. Therefore in 10 of the 14 patients the rib survived and bony reconstruction was satisfactory.

This is a case report of a patient who had a pectoralis major osteomyocutaneous flap procedure that incorporated a segment of the fifth rib for immediate reconstruction of a composite mandibular defect. The rib was vascularized through the periosteal circulation. The authors presented tetracycline labeling and technetium scanning documentation of bone survival.


Mandibular reconstruction was performed using a pectoralis major osteomyocutaneous flap. The outer table of the sternum was included as vascularized bone. Six successful cases were reported.


The authors described the reconstruction of the zygoma, temporo-mandibular joint, and hemimandible with a compound pectoralis major osteomyocutaneous flap that included portions of the sternum, sternal costal joint, and rib. The result of this successful reconstruction was compared to the movement of the normal temporo-mandibular joint.


Experience with 14 pectoralis major osteomyocutaneous flaps for reconstruction in patients who had undergone mandibulectomy for carcinoma was described. They reported three failures that they attribute to technical errors. In an attempt to improve the blood supply by means of the perichondrium they included a portion of the costal cartilage.


The authors described a modification of the pectoralis major osteomyocutaneous flap. Their modifications spare more of the muscle, resecting only a lateral segment of muscle in eight patients, seven of whom had successful reconstructions. This is a useful modification that spares a significant amount of the muscle.
## ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>Large rectangular flap covering the area above and below the clavicle laterally to the mid-deltoid.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>12 × 35 cm (primary closure with 7 cm width).</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Fasciocutaneous.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Supraclavicular artery.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td>Supraclavicular nerves (C3, C4).</td>
</tr>
</tbody>
</table>
Section 6F

ANTERIOR THORAX

Supraclavicular Artery Flap

CLINICAL APPLICATIONS

Regional Use
- Head and neck
- Pharynx
- Anterior chest

Specialized Use
- Facial resurfacing
Fig. 6F-1  A, Blood supply to supraclavicular artery flap. B, The supraclavicular nerves (C3, C4) arise from a common trunk, which descends for a variable distance before dividing into medial, intermediate, and lateral supraclavicular nerves. These supply the skin over the lower neck from near the midline to the acromioclavicular region and above the shoulder. They then pass in front of the clavicle to innervate the skin of the anterior chest wall to the level of the sternal angle and the second rib. The medial and lateral nerves, respectively, send twigs to the sternoclavicular and acromioclavicular joints.

**Dominant pedicle:** Supraclavicular artery
ANATOMY

Landmarks  Large rectangular surface covering from the base of the neck to the mid-deltoid, extending above and below the clavicle.

Composition  Fasciocutaneous.

Size  12 × 35 cm (primary closure with 7 cm width).

Arterial Anatomy

Dominant Pedicle  Supraventricular artery

Regional Source  Transverse cervical artery.

Length  1 to 7 cm.

Diameter  1 to 1.5 mm.

Location  The supraclavicular artery is reliably found in the triangle composed of the sternocleidomastoid muscle anteriorly, the trapezius muscle posteriorly, and the clavicle inferiorly. The supraclavicular artery is found 8 cm lateral to the sternoclavicular joint, 3 cm above the clavicle, and 2 cm posterior to the sternocleidomastoid muscle belly. In studies, the vessel is present 80% to 100% of the time. When the vessel is less than 1 mm in diameter, the surface area of the flap perfusion can be diminished.

Venous Anatomy

Venae comitantes run with the supraclavicular artery, draining into the transverse cervical vein. The diameter of the transverse cervical vein at its origin is 2.5 mm.

Nerve Supply

Sensory  The supraclavicular nerves (C3, C4). There are three distinct branches of the supraclavicular nerve: (1) the medial branch supplying the area of the sternoclavicular joint and onto the chest, (2) the middle branch supplying the area of the supraclavicular fossa extending onto the chest, and (3) the lateral branch extending to the acromial clavicular joint area.
VASULAR ANATOMY OF THE SUPRACLAVICULAR ARTERY FLAP

Fig. 6F-2  A, Cadaveric dissection of the supraclavicular flap demonstrating the supraclavicular artery running axially in the flap. B, Closeup of the triangle defined by the sternocleidomastoid, clavicle, and trapezius, with the pedicle visualized. C, A sizable pedicle is seen coming from the transverse cervical branch of the subclavian artery. D, Three-dimensional CT angiogram of a supraclavicular flap (anteroposterior view). The flap was infused almost 100%.
FLAP HARVEST

Design and Markings

Pencil Doppler ultrasound is used to locate the supraclavicular artery. The flap is designed laterally, extending toward the acromioclavicular joint. Dye studies have shown that in two thirds of cases the artery runs above the clavicle, although many clinical cases have shown that anastomosis with the nearby thoracoacromial artery and nearby perforating vessels explained perfusion below the clavicle. The design extends all the way to the area of the mid-deltoid muscle. Primary closure is obtainable if the flap is 7 cm wide or less.

Patient Positioning

The patient is placed in the supine position, with a shoulder bump pillow or towel creating an angle of as much as 45 degrees. The neck and the entire arm and hand are circumferentially prepared into the field.
GUIDE TO FLAP DISSECTION
The flap is dissected from distal to proximal in a subfascial plane. The initial dissection proceeds quickly. Care is taken as the area of the pedicle is approached. This can be confirmed by handheld Doppler. It is often helpful in the middle portion of the flap to use a transillumination technique to identify the location of the vessel. Once the pedicle is identified, the skin island incision can be completed if required. This can aid in transposition and rotation of the flap.

Fig. 6F-4

Flap halfway dissected, taking fascia of deltoid

Flap nearly completely elevated with vessels showing at its base

Fig. 6F-5

Tissue expander placed subfascially

FLAP VARIANT
Tissue Expansion
The supraclavicular flap has been used successfully in difficult cases requiring neck and cheek resurfacing, such as in extensive burns or cancer resections. Although large flaps can be harvested in this area with skin grafting of the donor site, great success has been demonstrated using tissue expansion. For this, the tissue expander is placed subfascially beneath the area of desired expansion in the supraclavicular region. The expansion process and the undermining from placing the expander tend to improve the vascularity of this area as a form of delay procedure. The amount of expansion is limited by tissue need and patient’s ability to tolerate expansion. The other advantage of tissue expansion is that the donor site is expanded; thus, even for large flaps, primary closure can be achieved.

Fig. 6F-5

Tissue expander placed subfascially
**ARC OF ROTATION**

**All Flaps**
The flap can reach the lower third of the face for resurfacing the neck or the area of the pharynx for pharyngeal reconstruction and lower third intraoral mucosal defects. The flap is also well suited for reconstruction of chest defects. The length of the flap may be extended by a vascular delay procedure down the arm (see Chapter 1).

**FLAP TRANSFER**
Once the flap is isolated on the supraclavicular pedicle, transfer can be performed through a subcutaneous tunnel or by direct connection to the defect. Surgical judgment must be used to see which of these options best accomplishes the reconstructive goal without compromising the pedicle.

**FLAP INSET**
In most cases, the inset will be at the level of the skin, which should be closed without tension. If the harvested flap is larger than the defect to be reconstructed, it may be helpful to deepithelialize the unneeded areas before inset to add vascularity and help bolster the closure.

**DONOR SITE CLOSURE**
Primary closure is obtainable with defects up to 7 cm wide. Larger areas can be closed primarily with extensive undermining; this will depend on the laxity of the patient’s skin. The internal mammary artery (IMA) perforators should be left intact so that the deltopectoral flap remains a secondary reconstructive option. One should consider skin grafting the donor site if there is too much tension on the closure. Tissue expansion is an option as an initial step to expand both the flap and the donor site, or as a secondary procedure to remove a skin graft.
CLINICAL APPLICATIONS

This 69-year-old man had an invasive squamous cell carcinoma of the cheek. He required a composite resection of the cheek with parotidectomy and cervical lymph node dissection. The remaining mucosa was mobilized for intraoral closure. This left a large soft tissue defect. The previous neck surgery and the lymph node dissection precluded the use of a submental flap. Free flaps would bring in nonmatching tissue. The other local tissue choices with best skin match were the supraclavicular and deltopectoral flaps. The deltopectoral would require at least one delay procedure and require a skin graft to the donor site. A supraclavicular flap was chosen as the best local choice. The lower neck incision was from the lymph node dissection and did not extend lateral to the sternocleidomastoid muscle.

Fig. 6F-7   A, The 6 by 6 cm defect and open neck from lymph node dissection. B, Design of the supraclavicular artery flap. The supraclavicular artery was localized with a Doppler probe in the dotted triangle of the SCM, trapezius, and clavicle. (Three Doppler points are marked by Xs.) The flap was designed 3 cm distal to the deltoid insertion.
Anterior Thorax

Fig. 6F-7  
C, The flap was elevated up to the vessels. The dissection did not specifically identify any vessels. D, The underside of the flap is seen; note some of the axialized vessels within the flap. E, The flap easily reached the defect. Rather than bury the flap with the necessary 180-degree rotation and flipping of the flap, with possible compression of the pedicle and bulk along the mandibular line, it was decided to pedicle the flap. F, After inset of the flap and primary closure of the donor site. G, After division and inset of the flap. Some of the pedicle was returned to the chest for aesthetics. (Case supplied by MRZ.)
This 60-year-old man presented with recurrent squamous cell tumor burden adjacent to the tracheostomal site.

Fig. 6F-8  A, Before flap reconstruction. B, Tumor ablation defect. C, Supraclavicular flap elevated, with blue background beneath the pedicle. D, The patient is seen 2 weeks postoperatively. (Case courtesy Ernest S. Chiu, MD.)
This 90-year-old man presented with persistent jaw pain and recurrent cheek squamous cell carcinoma, with cheek tissue radiation fibrosis.

Fig. 6F-9  A, The patient is seen preoperatively. B, Defect after tumor ablation. C, Supraclavicular flap harvested. D, The flap deepithelialized and ready for inset. E, The patient is seen 6 months postoperatively. (Case courtesy Ernest S. Chiu, MD.)
This 65-year-old man had an intraoral tumor that had failed radiation therapy. He also developed TMJ fibrosis that impaired the intercisal opening, thus requiring coronoidectomy and tumor resection.

Fig. 6F-10  A, Ablation of the intraoral tumor involving the gingivobuccal sulcus left a 5 by 6 cm defect. B, The planned flap was marked. C, The supraclavicular artery flap was elevated and D, rotated. E, The flap was tunneled into the ipsilateral neck and F, inset. There was no leak from the reconstruction, and the patient was able to tolerate a normal diet 6 months after surgery. (Case courtesy Ernest S. Chiu, MD.)
This patient sustained burns to the right side of the face and neck that were covered with skin grafts. A contralateral preexpanded supraclavicular artery flap was planned.

Fig. 6F-11  A and B, Preoperative AP and oblique views of the patient. C, The inflated expanders are seen in place. D, The intraoperative flap design was marked. E, The supraclavicular artery flap was raised and inset. F and G, Postoperative appearance. (Case courtesy Norbert Pallua, MD.)
This woman had a squamous cell carcinoma on the chin. After excision of the lesion, a supraclavicular artery flap was required for defect coverage.

Fig. 6F-12  A and B, AP and closeup preoperative view. C, After excision of the lesion, the supraclavicular flap was outlined and used to cover the defect. D-F, Twelve years after surgery, excellent tissue and contour reconstruction is evident, and the donor site scar is inconspicuous. (Case courtesy Norbert Pallua, MD.)
After sustaining a burn, this man developed keloids that severely restricted his neck movement. A unilateral preexpanded supraclavicular artery flap was planned for reconstruction.

Fig. 6F-13  A and B, The patient’s keloids restricted his neck movement. C, Expanders were placed preoperatively. D, Reconstruction was done with a unilateral preexpanded supraclavicular artery flap of 32 by 5 cm. E and F, The reconstruction resulted in improved contour and function. (Case courtesy Norbert Pallua, MD.)
This boy sustained severe burns to the face that had primarily been reconstructed with skin grafts. A bilateral preexpanded supraclavicular artery flap was planned.

**Fig. 6F-14**  A and B, The patient is seen preoperatively. C, Bilateral expanders were placed. D, The scar was resected and the defect covered with the supraclavicular artery flap. E, The donor site was closed primarily. F and G, The patient is seen postoperatively after full face reconstruction with the bilateral preexpanded supraclavicular flaps. (Case courtesy Norbert Pallua, MD.)
Pearls and Pitfalls

- The supraclavicular artery flap is a local flap that has the functionality of a free tissue transfer.
- Advantages include excellent skin color match, thinness, and pliability.
- CT angiography can be used to confirm the presence of the supraclavicular vessel before surgery, although this is not essential.
- A contralateral supraclavicular artery flap should be considered if, for one reason or another, the initially elevated flap cannot perform the reconstructive function.
- Because the flap is composed of skin and subcutaneous tissues only, the morbidity to the shoulder with this procedure is remarkably small.
- This flap can be compared to the deltopectoral flap, in which skin grafting of the donor site is often required.
- If care is taken in elevating the supraclavicular artery flap and a second flap is required, careful undermining at the time of closure of the supraclavicular artery flap will leave the deltopectoral flap and its territory as an option for a second flap for salvage. This would most likely require skin grafting but provides a valuable and viable salvage flap option.

EXPERT COMMENTARY
Ernest S. Chiu

Indications
The supraclavicular artery island flap is my flap of choice for most lower third face and neck oncologic defects. Its use has been described for reconstruction of neck burn scar contracture and wounds. The flap can be successfully used despite various comorbidities, including obesity, poor nutrition, diabetes, and smoking. Flap survival is no different than for any traditional flap.

Relative contraindications have been limited to patients who have had previous bilateral neck dissections and/or radiated necks. Still, our group routinely performs supraclavicular flap harvest successfully in these challenging clinical settings. An alternative flap is always planned but rarely used (less than 2%).

Advantages and Limitations
The supraclavicular artery island flap is a thin, pliable, reliable, regional, axially based, innervated, fasciocutaneous flap with good color match for many head or neck reconstructive defects. There is minimal shoulder donor site morbidity. The limitation of the flap is the pedicle vessel diameter and length, which determines its perfusion zone. As in all flaps, this can only be determined after the flap is elevated.

Continued
Anatomic Considerations

Personal Experience and Insights

Complications were encountered in several of our cases but did not dampen our enthusiasm for trying again with this flap, since the results were very acceptable as judged by me as well as board-certified ENTs and plastic surgeons. Most of the major complications occurred in pharyngeal reconstruction cases (20% to 30%). All of these patients had prior failed chemoradiation therapy protocols. Patients with fistulas had comorbidities such as advanced tumors, poor nutrition, significant smoking history, radiation therapy, and previous tracheotomies. Although this rate seems high, it is similar to other reported fistula rates (5% to 53%) using fasciocutaneous and myocutaneous flaps. All leak cases resolved without further surgical intervention. Patients were able to drink and eat using their neopharynx and continue with daily routines. All patients agreed they would undergo the same procedure again. Suturing any vascularized tissue to poorly perfused, irradiated tissue is worrisome; therefore adequate debridement and removal of nonvascularized tissue is advised. Supraclavicular flap distal tip necrosis has been observed, but this rarely jeopardizes final outcome. Regional muscle flaps have more bulk but will atrophy and cause fibrosis. Unfortunately, excessive scarring and muscle fibrosis can lead to oropharyngeal stricture formation.

Recommendations

Planning

As with many perforator flaps, preoperative CT angiography is routinely performed so that the reconstructive surgeon can determine whether the pedicle is present or was previously injured. This is not always necessary but is helpful. It is paramount to have good preoperative planning discussions with the head and neck oncologic surgeon. A radical neck dissection (level V lymph node) is rarely performed today; therefore the thyrocervical trunk is usually preserved on the ipsilateral side. When one side of the neck has been previously irradiated or surgically operated on, the contralateral shoulder is used to avoid the challenge of scar tissue dissection. In every patient with a central neck problem, there are two potential shoulder flaps.

Technique

At the beginning of each case, folded towels are placed beneath the patient’s shoulder to serve as a bump to improve exposure. The area is prepared with Betadine, including the neck and the entire arm and hand circumferentially. Intraoperatively, a skin Doppler signal is confirmed in the triangular fossa bordered by the clavicle as well as the sternocleidomastoid and trapezius muscles.

A 6 to 7 cm wide elliptical island flap can be designed over the shoulder and supraclavicular region to include the proximally detected signal. The flap is dissected from distal to proximal in a subfascial plane toward the pedicle using electrocautery. In my early operative experience, I was not able to harvest a supraclavicular artery flap because the pedicle was inadvertently injured when an anterior-to-posterior harvest direction was attempted. The pedicle was very small, tortuous, and difficult to identify. Today a distal-to-proximal flap harvest approach is recommended to decrease risk of pedicle injury. Since converting to this technique, pedicle injury has not been observed.

Once in the Doppler-confirmed signal vicinity, I switch to blunt bipolar forceps as in a perforator flap dissection. Frequently, a Doppler signal can be detected (3 to 10 cm away from its origin) on the subfascial surface well before approaching the pedicle origin. After the pedicle has been identified, the proximal skin island is divided so that the island flap has ample room to rotate. The length, vessel diameter, and location of the pedicle entering the
flap island are the limiting factors determining the tissue volume that can be transferred. During flap harvest, multiple infraclavicular nerves (C4-C5) may be encountered. They are sensory nerves that can be divided to allow an increase in pedicle length. If the sensory nerves are not divided, referred sensation can be noted in the skin paddle when touched. The spinal accessory nerve runs posterior and medial to the main pedicle and should not be encountered during flap dissection. Still, the surgeon must be aware of anatomic variations.

Intraoperatively, the distal tip is trimmed until healthy bleeding tissue is noted. We routinely design the distal flap tip to include skin from the mid-deltoid area. All flaps are deepithelialized and reduced in size to fit the ablative defect proportionally. The skin paddle perfusion originates through the dermal plexus; therefore it is important to minimize inadvertent holes in the deepithelialized proximal dermis. Defatting on the flap underside can be done judiciously.

Other groups have recommended a tunneled technique to minimize scarring and donor site morbidity with acceptable results. However, since many of these patients already have neck incisions from prior surgery, we do not hesitate to connect the proximal skin island flap to this previous incision. Tunneling of the supraclavicular flap under irradiated tissue or areas of previous scarring is not recommended; the scar band may impair blood flow to the distal flap where the transferred tissue is often needed the most. Flap insetting and pedicle visualization also becomes easier. Skin necrosis at trifurcation sites has not been observed. Flap inset technique is the surgeon’s preference. Buried flaps are not monitored, since the flap has both an artery and vein originating from its parent vessels.

The donor site is closed after flap inset. Both anterior and posterior wide undermining is usually required. A shoulder drain is not necessary, because the dead space is closed snugly. Any flap designed wider than 8 cm may be difficult to close, and skin grafting should be performed without hesitation. Although a scar may be noticeable when the patient is shirtless or in a patient wearing a tank top (especially women), compromised shoulder function has not been observed in our series.

Other investigators have stated that the vessel caliber and pedicle length are variable and that these are not always present. Even though the supraclavicular flap has been used previously as a free tissue transfer flap, we advise planning the use of a contralateral supraclavicular artery island flap or more traditional regional or free flaps as a second option, because these vessels can be small, injured, scarred, or absent.

References

EXPERT COMMENTARY
Norbert Pallua, Timm P. Wolter

Indications
The supraclavicular artery flap has become a workhorse in head and neck reconstruction. Since the original 1997 description of the flap, we have published our experience with tunneling and preexpanding the flap. Its use in burn reconstruction of children is well documented. Originally thought to be only used for limited indications in severe mentosternal contracture, the supraclavicular flap is now used for a wide variety of applications, and an increasing number of publications report its use.

The supraclavicular artery flap allows reconstruction of an enormously important area for social interaction and permits restoration of full range of motion for neck movement. Indications include scar reconstruction or tumor-related defect coverage in the head, neck, and postauricular or jugular area. As an ultrathin, preexpanded flap it can be used for hemifacial resurfacing. Intraoral defects often encountered in maxillofacial surgery can be covered using this flap.

Advantages and Limitations
The main advantage of the supraclavicular artery flap is its soft, pliable tissue with very good color and texture match for the head and neck region. This sensate and mostly hairless tissue is ideal for facial reconstruction. Because more distant regions have less color and texture match, it is often superior to free flaps in these indications. Also, without the need for microsurgery, the procedure is safe and faster, making it suitable for patients with compromised health, such as those in the early postburn period. The donor site at the shoulder allows the scar to be inconspicuous.

The downside of the flap includes the surgeon’s learning curve, as in every new procedure. Also, in most cases it requires a staged surgery. When using the flap as a pedicled flap, good patient compliance is essential. Using preexpansion, expander filling can be associated with problematic patient compliance, possible infection, and expander failure.

Anatomic Considerations
In my experience (N.P.), the vessel is constant in 100% of cases. I have never lost a flap because of an absence of the supraclavicular artery. In contrast to the description in the chapter, I use the external jugular vein as a landmark as opposed to the trapezius muscle. The pivot point can be reliably located in the triangle between the external jugular vein, the clavicle, and the lateral head of the sternocleidomastoid muscle.

Personal Experience and Insights
The indications for the supraclavicular artery flap have expanded and evolved since the original description. Preexpansion allows much larger areas to be reconstructed, easier closure of the donor site and a better vascularization of the flap. Another variation of the flap was the inclusion of an osseous chip from the clavicle. This made tracheal reconstruction possible and offered a solution for the complex reconstruction of tracheocutaneous fistulas. Another exciting possibility is the use of the supraclavicular as a free flap.

A change in my technique is that I am now raising the flap not over the shoulder, as in most publications, but using a more anteriorly lying skin island. The tissue in the acromial fossa is even more pliable than the shoulder area. Also, surgical preparation is facilitated.
It should be noted that ancillary or secondary procedures are quite common, including lipofilling, thinning of the flap by liposuction, and suspension of the flap by bone anchors or by a palmaris tendon strip.

**Recommendations**

**Planning**

Because the vessel is constant, preoperative CT angiography is unnecessary in most cases. Handheld Doppler examination will confirm the presence of the vessel in cases of doubt (such as in patients who have had previous surgeries).

The shoulder without preexisting scarring should be chosen. However, when both shoulders are burned or bilateral supraclavicular artery flaps are planned, the flap can even be raised with some scarring. The scar can be excised during a later procedure.

**Technique**

As described in this chapter, the flap is raised from lateral to medial using a Doppler probe or transillumination to identify the vessel. I recommend placing the patient in a supine position with a freely movable arm. A surgical table with a removable shoulder piece facilitates access. Closure of the donor site can almost always be performed primarily.

**Postoperative Care**

The flap must be carefully monitored. It is most important to reduce any tension on the pedicle; therefore the arm should be held elevated. In select cases (such as children and agitated patients), a postoperative Omega-type cast should be applied to immobilize the arm and the head.

**Complications: Avoidance and Treatment**

In very large flaps, the flap can develop venous congestion at the distal end. Leech therapy can be helpful. The most important factor for optimal blood flow is the position of the arm. I routinely use perioperative and postoperative antibiotic prophylaxis to prevent flap loss from infection.

**Take-Away Messages**

The flap has unique possibilities for reconstruction or resurfacing of the head and neck area. It can be safely used in adults, children, and patients with compromised health. The flap can be embedded in a reconstructive treatment plan with multiple procedures. When one is defining this treatment plan, the surgical sequence should consider placement of tissue expanders and adjunctive procedures. Refinements include lipostructuring, flap thinning, and flap suspension.

**Reference**

Bibliography With Key Annotations


The authors investigated the morphology of the nonperforating cervical cutaneous branch in the lateral cervical triangle using 65 (130 sides) donated cadavers. They found the branch in 104 of the entire 130 sides (80.0%). In the majority (72.1%), the cutaneous branch did not cross the clavicle or acromion but supplied the dorsolateral cervical area. The branch was originated from the superficial cervical artery close to the posterior belly of the omohyoid muscle and immediately lateral to the external jugular vein. The constant vein, if present, drained into the external jugular vein. Their observations and measurements (length and diameter) suggested that the nonperforating cutaneous branch is useful for a pedicle of the dorsolateral cervical flap in Japanese people. However, detailed morphologies differ from the previous studies published in western countries.


The anterolateral thigh (ALT) flap has become a popular option for reconstructing a variety of soft tissue defects, especially in the head and neck. Thinning of the flap may extend its usefulness to situations requiring less bulk; the successful use of this technique has previously been described in Asia. However, similar results have not yet been produced in the West. To investigate this, the authors proposed that “one-stage thinning of the ALT flap does not disrupt the blood supply to any area of the flap skin.” A series of 10 ALT flaps were raised from Western European cadavers. The arteries of the flaps were injected with India ink and latex rubber, and six of the flaps were cleared by the Spalteholz technique. Patterns of dye filling were compared in full-thickness and thinned specimens, and the arterial organization within the subcutaneous fat was studied. The authors saw 14 perforators in 10 ALT flap dissections. These arose from the descending branch of the lateral circumflex femoral artery in eight cases and from the transverse branch in two cases. Large branches from the perforator were seen to form an arterial plexus at the level of the deep fascia, which communicates with the subdermal plexus supplying the skin. Further branches arose from the perforator and traveled obliquely through the fat to reach the subdermal plexus. In the thinned cadaver ALT flaps, dye perfusion did not reach the distal portions of the subdermal plexus. There was reduced dye filling in comparison to the full-thickness specimens. Thinning of the ALT flap reduces arterial perfusion in cadaver specimens. This allows rejection of the null hypothesis. The fascial plexus and the oblique vessels supplying the subdermal plexus are likely to be damaged or removed during thinning. This may explain the observed reduction in subdermal-plexus filling in the thinned specimens. In the clinical setting, disruption of the arterial supply in this manner could lead to ischemia and skin necrosis in thinned flaps. One-stage thinning of the ALT flap may not be advisable in the Western population.


Patients undergoing radial forearm free flap for hypopharyngeal reconstruction were retrospectively reviewed; 104 patients underwent this procedure between 2001 and 2007. Fistulas were classified as mild or severe, depending on the response to conservative management. Demographics, operative details, pathology, and postoperative course were recorded as the prognostic variables. Univariate analysis and a logistic regression model were used to identify associated factors. Pharyngocutaneous fistula developed in 30 (28.8%) patients. Recurrence, cancer stage, cancer location, type of ablative surgery, and the addition of other oncologic procedures were identified as significant predictors of fistula formation. Fistula significantly increases hospital stay and recipient site complications such as flap survival, infection, and bleeding. Functional results such as diet, deformity, and socialization were also negatively affected by fistula development. One third of the cases responded to conservative management, and 20 cases required a surgical procedure to definitively close the fistulous tract. Fistula formation remains
Anterior Thorax

• 6F: Supraclavicular Artery Flap

A significant cause of morbidity associated with hypopharyngeal reconstruction. Postoperative course and successful preventive strategies are discussed.


Eighty-six patients with anterior neck burn sequelae underwent scar resection up to the limits of the aesthetic unit of the neck and immediate resurfacing with a scapular-parascapular free flap (the extended scapular flap). The flap was raised in all patients above the deep fascia as a thin skin-subcutaneous tissue flap, providing an initially acceptable aesthetic result. The flap was anastomosed to the facial artery and vein. The donor area was closed directly, or a 4 to 5 cm wide skin graft was used that could be completely removed in a secondary procedure if the patient requested it. There were 4 failures early in the series, but no losses in the last 70 patients. To improve the final aesthetic result, 45 patients underwent complementary defatting procedures (average three) and Z-plasties initiated 30 days after the initial surgery at intervals of 1 month. Analysis revealed 96% good aesthetic results (as determined by the cervicomental angle obtained and the subjective opinion of the patients). There were no recurrences of scar contractures, and good function of the neck was regained in the majority of the patients. Thus anterior neck burn sequelae can be safely treated with en bloc resection and resurfacing using this flap.


A bilateral extended scapular (scapular-parascapular) free flap was used in five patients with severe facial burn sequelae for complete resurfacing of the face with the exception of the nose, which was reconstructed in a separate operative procedure. All flaps survived. Four were used for complete face resurfacing and one for neck and partial face resurfacing. The results were classified subjectively according to both patient and surgeon opinion. Good to fair results were obtained. The authors stated that this method might be further explored to obtain better results in these difficult cases.


The author described a compound flap that uses skin from the anterior chest on a narrow segment of pectoralis major muscle, with its underlying axial neurovascular bundle. This flap was used successfully to reconstruct large defects in four consecutive patients. The author’s experience with this flap suggests that it may be more versatile than the deltopectoral flap.


The collaboration of surgeons, radiation oncologists, chemotherapists, dentists, oral surgeons, prosthodontists, and speech therapists has led to major advances in the management of the difficult cancers of the head and neck area. The advent of myocutaneous flaps and the facilitation of microsurgical free flaps have ushered in an era of one-stage reconstructions to shorten the hospital stay and improve the overall therapeutic, functional, and cosmetic results.


The radial forearm flap, although widely used, has been criticized for the poor quality of its donor site. To investigate the causes of morbidity, 100 radial artery free flap donor sites were reviewed. Sixty-seven patients required skin grafting (group 1), and the remaining 33 patients were closed directly (group 2). Seventeen patients in the series had compound osteocutaneous flaps (group 3). Wound healing proved to be a significant problem in groups 1 and 3, and fracture of the radius occurred in 4 of the 17 patients in group 3 and was the most significant cause of morbidity. The radial artery was reconstructed in 12 patients, but only 6 of the arteries (50%) were patent at the time of review. In light of this experience, the authors no longer reconstruct the radial artery as a matter of routine. The donor defect is closed directly wherever possible using an ulnar artery-based transposition flap when required. A “boat-shaped” osteotomy is used in preference to right-angled bone cuts when harvesting a segment of radius to avoid the complications and sequelae of fracture. These changes in surgical technique have improved the acceptability and minimized the problems associated with this donor site.

The authors reported their experience with a new procedure: the combination of a prefabricated superficial temporal fascia flap and a submental flap performed in an African hospital on five patients with cheek deformities caused by noma. The prefabricated superficial temporal fascia flap makes the inner lining of the cheek, which is anchored on the peripheral scar tissue. The submental flap is released during the second operation and makes the outer lining. The main advantages are the excellent aesthetic color of this last flap and the short distance between the donor site and the recipient site. Moreover, the submental flap is positioned in a single operation (when the outer-lining reconstruction is performed with a deltopectoralis flap, a third operation is necessary to cut the pedicle). None of the flaps failed, and the functional results were good. The prefabricated superficial temporal fascia flap and submental flap are versatile and reliable flaps, with reasonably long vascular pedicles, that can be used successfully, even under suboptimal conditions in weak patients with huge defects of the face.


The cervicohumeral flap has proven useful in head and neck reconstruction. The limitation of the flap appears to be its length. Its major disadvantage is a lack of predictability of length of survival beyond the deltoid insertion.


Free tissue transfer is under certain circumstances an ideal reconstructive method for skin and soft tissue defects of the head and neck region. These are large multilayered defects, recurrences after previous reconstructive methods, in aesthetic disturbances resulting from the use of local flaps, in difficult reconstructive areas associated with chronic infection and radiotherapy, and when local tissue is not available. From 1987 to 1993 the authors performed 30 reconstructions of the surface of the head and neck region with free flaps, mainly the forearm flap and the scapular flap, but also the latissimus dorsi flap, and in one case the rectus abdominis flap were used. There were no flap failures. In only one case of a forearm flap the authors saw delayed healing of the donor defect. There was no functional impairment of the donor defect. All cosmetic results were acceptable. Flaps from the trunk mainly showed considerable differences in color and texture to the surrounding skin.


The authors reviewed 145 patients who underwent 148 total reconstructions of the hypopharynx and cervical esophagus between 1970 and 1989. The types and numbers of reconstruction included 45 deltopectoral flaps, 35 myocutaneous flaps, 19 colon interpositions, 23 gastric transpositions, and 26 free jejunal transfers. Median hospitalization was 51 days for deltopectoral flaps, 24 days for myocutaneous flaps, 28 days for colon, 30 days for gastric, and 14 days for jejenum. Median resumption of oral intake was 92 days for deltopectoral flaps, 19 days for myocutaneous flaps, 12 days for colon, 13 days for gastric, and 9 days for jejunum. Functional failure, defined as the inability to maintain adequate nutrition without tube feedings, was 40% for myocutaneous flaps, 42% for colon interposition, 17% for gastric transposition, and 20% for free jejunal transfer. Microvascular free jejunal transfer has become their method of choice for reconstruction of the hypopharynx and cervical esophagus. Gastric transposition is an alternative when resection of the thoracic esophagus is necessary.


The supraclavicular artery island flap is a useful regional option in head and neck reconstruction. Previous studies recorded pedicle length, caliber, and ink injection studies of the supraclavicular artery. This study presented a three- and four-dimensional appraisal of the vascular anatomy and perfusion of the supraclavicular artery island flap using a novel computed tomographic technique. Ten supraclavicular artery island flaps were harvested from fresh cadavers. Each flap was injected with contrast media and subjected to dynamic computed tomographic scanning using a GE Lightspeed 16-slice...
scanner. The entire skin paddle was perfused in the majority (nine of 10) of flaps. One of the flaps was perfused only 50%. In this case, the pedicle artery was found to be much smaller than the other flap pedicles. Direct linking vessels and recurrent flow by means of the subdermal plexus were found to convey the flow of contrast between adjacent perforators. This explains how perfusion extends to adjacent perforators by means of interperforator flow, and how perfusion is maintained all the way to the distal periphery of the flap. Using this imaging technique, the authors elucidated the vascular anatomy of the supraclavicular artery island flap. This study confirmed previous clinical findings that the supraclavicular artery island flap is a reliable option, giving surgeons new information for future flap refinement.


The supraclavicular island flap has been used successfully for difficult facial reconstruction cases, providing acceptable results without using microsurgical techniques. The authors use this regional flap in reconstructing various head and neck oncologic defects that normally require traditional regional or free flaps to repair surgical wounds. A pedicled supraclavicular artery flap was used to reconstruct head/neck oncologic defects. Complications and functional outcomes were assessed. Head and neck oncologic patients underwent tumor resection followed by immediate reconstruction using a supraclavicular artery island flap. Ablative defects included neck, tracheal-stomal, mandible, parotid, and pharyngeal walls. All flaps (18) were harvested in less than 1 hour. All ablative wounds and donor sites were closed primarily and did not require additional surgery. Major complications included a complete flap loss when the vascular pedicle was inadvertently divided and pharyngeal leaks. The leaks resolved without surgical intervention, and both patients regained the ability to swallow using their neoesophagus. Minor complications included donor site wound dehiscence and cellulitis. None of the patients reported functional donor site morbidity. This thin flap is easy and quick to harvest, has a reliable pedicle, and has minimal donor site morbidity. It is now the authors’ flap of choice for many common head and neck reconstructive problems.


Laryngeopharyngeal reconstruction continues to challenge in terms of operative morbidity and optimal functional results. The primary aim of this study was to determine whether complications can be predicted on the basis of reconstruction in patients undergoing pharyngectomy for tumours involving the hypopharynx. In addition, the authors detail a reconstructive algorithm for management of partial and total laryngeopharyngectomy defects. A retrospective review was performed of 153 patients (118 men, 35 women) undergoing flap reconstruction for 85 partial and 68 circumferential pharyngectomies at a single institution over a 10-year period. The total operative morbidity and mortality rate was 71% and 3%, respectively. Pharyngocutaneous fistula was increased in patients undergoing salvage pharyngectomy for radiation failure compared with primary surgery. Tracheoesophageal speech was the method of voice restoration in 44% of patients. Oral diet was achieved in 93% of patients however, 16% required gastrostomy tube feeds for either total or supplemental nutrition. The operative morbidity associated with pharyngectomy reconstruction is substantial in terms of early and late complications. The authors were able to predict morbidity by defect extent and reconstruction type and initial treatment modality. Swallowing function was acceptable; however, less than half of the patients undergoing pharyngectomy had tracheoesophageal puncture voice restoration.


Nondelayed regional skin flaps for reconstruction following radical ablative surgery in the head and neck have become a significant advance. Radical extirpation of large, recurrent, or postirradiation persistent cancer would be prohibitive without the use of regional skin flaps in reconstruction. The incorporation of portions of rib, clavicle, or scapula within a skin flap has allowed reconstruction of the mandible for both functional and cosmetic improvement.

Reconstructive procedures in the head and neck region use a wide range of flaps for defect closure. The methods range from local, mostly myocutaneous flaps and skin grafts to free microsurgical flaps. To ensure a satisfactory functional and aesthetic result, good texture and color of the flap are always essential. Moreover, the donor site defect needs to be reduced, with no resulting functional or aesthetic impairment. The authors found that the shoulder provides an optimal skin texture match to the neck and face. In cadaver dissection, a vascular pedicle extending from the transversal cervical artery with two accompanying veins was found to vascularize a defined region around the shoulder cap. In line with these findings, the previously described fasciocutaneous island flap, nourished by the supraclavicular artery, was developed further and used purely as a subcutaneously tunneled island flap. The tunneling maneuver significantly improves the donor site by reducing scarring. The flap is characterized by a long subcutaneous pedicle of up to 20 cm. The pivot point is in the supraclavicular region and allows the flap to be used in the upper chest, neck, chin, and cheek. The authors introduced the anatomic features and presented clinical cases underlining the surgical possibilities of the flap in reconstructive procedures with expanded indications.


Wide tissue defects on the face and neck often require distant flaps or free flaps to achieve a tension-free reconstruction and an acceptable aesthetic result. The supraclavicular island flap is a versatile and useful flap that can be used in large tissue defects. Because of its wide arc of rotation, which ensures a 180-degree mobilization anteriorly and posteriorly, the flap can reach distant sites when harvested as a pure island flap. The main vascular supply of the flap, the supraclavicular artery, a branch of the transverse cervical artery, or, less frequently, of the suprascapular artery, although reliable, is not a very large vessel. In some particular cases, when there is too much tension or the angles are too tight, the vascular supply of the flap can be difficult, and special care must be taken to avoid flap failure. To avoid this problem, the authors started harvesting the flap not as a pure island flap but with a fascial pedicle, thin and resistant, which ensures good reliability. When a higher tension rate is present, it avoids the risk of excessive traction or kinking of the vessels. Twenty-five consecutive patients with various defects located on the head, neck, and thorax area were treated in the past 2 years using the modified supraclavicular island flap. There was no flap loss or distant necrosis of the flap, and there was marginal skin deepithelialization in only two cases, which only required minor surgery. Postoperative morbidity was low, similar to the classic supraclavicular island flap, with primarily closed donor sites, except for one case, and tension-free scars. The authors demonstrated that the modified supraclavicular island flap is a reliable and safe flap that gives a good aesthetic result with low risk concerning the viability of the transferred skin. The technique, similar to supraclavicular island flap harvesting, is easy to perform and is attractive in patients at risk for poor or delayed healing, such as smokers or patients with complex medical histories.


The objectives of this study were threefold: to develop a scheme for classification of hypopharyngeal defects, to establish a reconstructive algorithm based on this system, and to assess the functional outcome of such reconstruction. The authors performed a retrospective review of their 14-year experience with 165 consecutive microvascular reconstructions of the hypopharynx in 160 patients. The treatment algorithm for microvascular hypopharyngeal reconstruction was based on the type of defect with partial defects with radial forearm flaps, circumferential defects reconstructed with free jejunal flaps, and extensive, multilevel defects reconstructed with rectus abdominis myocutaneous flaps. The authors concluded that microvascular reconstruction of pharyngeal defects is highly successful with few postoperative complications. With appropriate flap selection, functional outcome can be optimized.

This investigative study examined the anatomy of 20 osteomyocutaneous flaps in 10 fresh cadavers and in 8 clinical patients. In the authors’ series, 80% (type I) of the major vascular pedicle arose from the thyrocervical trunk. In 20% (type II), the major pedicle arose separately from the subclavian artery. The regions perfused by the vascular trunk were further examined with micropaque and Prussian blue injections through the transverse cervical artery. Consistent areas of cutaneous staining as well as bony staining were noted over the shoulder, arm, and back and into the scapula itself. Experience with eight clinical applications of this osteomyocutaneous flap resulted in successful healing with an excellent aesthetic and functional result. Long-term follow-up was maintained on the patients for up to 36 months. Panorex radiographs and biopsies of the grafted bone were obtained on several patients. These disclosed evidence of bony remodeling and viable bone tissue. Tetracycline labeling also revealed evidence of active bony turnover.


This review of 182 consecutive burn patients needing surgery found that they underwent 233 separate episodes for skin grafting. Appropriately, only a fraction of this number required some form of vascularized flap, with 14 patients having 21 local fasciocutaneous flaps. Six were elevated in previously skin grafted regions, which is an advantage peculiar to this flap type. Three flaps (14%) suffered major complications requiring a second surgical intervention. Only six of all flaps were used for acute burn wounds, but two of the three complications accrued in this subset, with one directly attributable to wound infection. Because most flaps were required for either coverage or release of contractures about joints, it has been recommended that the initial surgical approach for treatment of the acute wound in these regions be altered to preserve the fascial plexus whenever possible to permit the use of this simple and expedient alternative if it is needed later.


Reliable information on cost and value in microsurgery is not readily available in the literature. Driving factors for cost, determinants of complications, and cost-reduction strategies have not been elucidated in this population, despite such progress in other areas of medicine. Clearly, the time-consuming and costly nature of this endeavor demands that appropriate indications and patient management be delineated to operate proactively in this cost-conscious time, financial and outcome determinations are critical. One hundred seven consecutive free tissue transfers performed from 1991 to 1994 by a single microsurgeon were studied. Retrospective chart review for clinical parameters was combined with analysis of hospital costs and professional charges. Operating room and anesthesia costs were based on a microcost analysis of actual operating room time, materials, labor, and overhead. Other patient level costs were generated by Transition 1, a hospital cost-accounting system. The following issues were addressed: (1) flap survival, (2) total costs and length of stay for all free flaps, (3) payments received from various insurers, (4) breakdown of operating room costs by labor, supplies, and overhead, (5) breakdown of inpatient costs by category, (6) additional costs of complications and takebacks, (7) factors associated with complications and flap takebacks, and (8) cost-reduction strategies. Mean free flap operating room costs (exclusive of professional fees) ranged among case types from $4439 to $6856 and were primarily a function of operating room time. Elective patient cases lasted a mean 440 minutes. There was a large disparity in reimbursement: private insurers covered hospital costs (not charges) completely, whereas Medicare paid 79% and Medicaid only 64%. Length of stay, operative procedures, and complications had the greatest influence on inpatient costs in this group of free flap patients. Potential cost savings as a result of possible practice changes (such as shortening intensive care unit stays and avoiding staged operations) can be predicted. This analysis caused a revision in these institutions’ practice patterns and laid the foundation for planned outcome studies in this population.


The so-called super-thin flap was devised in China, and these flaps have been in general use since about 1982. However, detailed descriptions of the flaps have rarely appeared in English-language

The super-thin flap technique was first devised in China. Flaps thinned by this technique are especially useful in the neck, face, or hands of patients with extensive burn scarring, where the combination of thinness and suppleness is needed. However, some of these radically thinned flaps may develop superficial or full-thickness necrosis because of the unpredictability of survival of the super-thinned area. The authors presented a technique of microvascular augmentation of the blood supply of the thinned flap, an example of so-called supercharging.


The usefulness of the free or pedicled superficial cervical artery skin flap in reconstructive surgery of head and neck burns is reported. This flap can be made with the pivot point near the cervical region. Moreover, it can be elevated as a free or long vascular pedicled flap. Therefore, it is widely applicable in reconstructing the scar contractures of the head and neck, particularly in extensively and deeply burned patients.


A team of two head and neck surgeons and two plastic surgeons performed 305 microsurgical free flaps for defects of the head and neck over a 9-year period, with a success rate of 91.2%. The authors reviewed their technique and complications. The radial forearm flap and free jejunal transfer have become the preferred choices for intraoral reconstruction and pharyngoesophageal reconstruction, respectively.


The prefabricated induced expanded (PIE) supraclavicular flap refers to the staged transfer of an expanded supraclavicular skin with a fascia flap used as the carrier. In three patients, the authors used PIE supraclavicular flaps to successfully reconstruct a total forehead and two major nasal defects. Their first PIE flap confirmed the feasibility of the method but necessitated two microvascular free flaps. In the ensuing two patients, the authors reduced the need for microvascular anastomoses by using simple pedicled flap transfers in either or both stages. Whenever feasible, the preferred method consists of transferring a temporoparietal fascia flap to a subcutaneous pocket in the ipsilateral supraclavicular fossa and simultaneously placing a skin expander under both the fascia flap and the supraclavicular skin. After adequate expansion, the fascia becomes incorporated within the capsule of the expander, and the composite capsulofasciocutaneous flap can be safely transferred to the facial defect as the PIE flap.


Few procedures offer the surgeon a greater opportunity to exercise surgical and aesthetic judgment than the design and implementation of local flaps about the head and neck. Considerations include skin color and texture match; adequacy of flap blood supply; size, location, and characteristics of the donor site defect; functional capability of the proposed flap; nature of skin tension lines created; and number of surgical procedures required. The author presented a systematic approach to local flap design and implementation and illustrations of the geometric principles involved.


Postburn neck contractures still represent a surgical challenge because of their exposed location and early operative treatment is necessary for both functional as well as aesthetic reasons. An excellent functional result was obtained by using a supercharged super-thin occipitocervicodorsal flap, as described by Hyakusoku et al, to repair a large defect of the anterior neck following a very wide neck burn operations.
contracture release. In this case report, the technique and its advantages among the other reconstructive modalities were discussed briefly.


Various authors have reported different failure rates for the cervico-humeral flap. The authors attempted to explain these occurrences in light of recent experimental and clinical work, which has increased their knowledge of the detailed blood supply of the supraclavicular fossa and shoulder region. In particular, the role of a fasciocutaneous vessel in the supply of a proximally based shoulder flap was stressed. Division of this vessel may occur during proximal mobilization of the cervico-humeral flap. This fundamentally alters the nature of the flap and may be the key to the varying failure rates. The implications of this for fasciocutaneous flaps in general were discussed.


The supraclavicular flap is an important method for reconstruction of the neck. The authors attempted to clarify the mechanism of blood flow into the supraclavicular flap based on the thoracic branch of the supraclavicular artery. Additionally, they discussed the clinical application of such anatomy. The authors stated that the pectorally extended supraclavicular flap could be used to repair defects on the ipsilateral or contralateral face, neck, and anterior thorax.


Microvascular free tissue transfer has in many cases replaced classic flap techniques and is now an established workhorse for head and neck reconstructions. The authors reported a retrospective study of over 300 patients who had microvascular free flap reconstructions in head and neck cancer surgery in Finland during a 10-year period. The operations were performed in the University Hospitals by plastic surgeons, ENT specialists, or maxillofacial surgeons. The most reliable flap in terms of survival was the radial forearm flap. The ever-improving success of microvascular free tissue transfer has made it a useful procedure for head and neck reconstructions. There is also a growing need for microvascular team surgery in the field of head and neck cancer therapy.


Both of these myocutaneous flaps can supplant forehead and deltopectoral flaps in certain indications. They are additional arterialized flaps for the armamentarium of the reconstructive surgeon, and can be useful in many repairs in the head and neck region.


Repairing the cervico-mandibular angle following neck burns is a major problem. Several artistic landmarks show its aesthetic importance. From a functional point of view, the authors showed the positive consequences of rebuilding using the results from 101 patients with neck burns. In principle, the treatment involves maximal use of healthy skin, and the separate reconstruction of the horizontal and vertical parts of the neck.


Fasciocutaneous flaps are available anywhere in the body—literally from head to foot. Some hair-bearing flaps, the parasternal flap, and some forearm and lower extremity flaps may be useful for coverage of soft tissue defects when a relatively simple one-stage procedure is preferred. The fasciocutaneous flaps described here are long and narrow, with a length to width ratio of up to 5:1. Although these flaps are not the ultimate solution to all reconstructive problems, they are especially useful in the treatment of burn scar contractures and chronic ulcerations such as those that result from the extravasation caused by chemotherapeutic agents. Of particular importance is the fact that the use of these flaps does not preclude the use of other flaps later, should this be necessary. Specific indications for these flaps must always be kept in mind in relation to other reconstructive alternatives.

The bilateral transverse cervical arteries of 16 fresh cadavers were exposed by an infraclavicular midline approach. Each artery was cannulated, and methylene blue dye was infused to delineate the skin territory subserved by the vessel. The two major infusion skin patterns obtained allowed fashioning of a thin fasciocutaneous flap incorporating supraclavicular skin, which was based on the transverse cervical artery or a larger flap additionally incorporating upper back skin and varying amounts of trapezius muscle, when the artery had a dorsal scapular artery branch. Depending on the skin pattern, either scapula or clavicle could be transferred with the other soft tissues. The skin territory of the transverse cervical artery is caused to vary by the presence or absence of its dorsal scapular artery branch. The supraclavicular portion of the flap is recommended for repair of facial and nasal lesions because of its close match in color and texture to facial skin. Oral lesions can also be reconstructed with this flap because of its pliability. The free flap based on the transverse cervical artery pedicle appears to be a useful addition to the armamentarium of flaps for head and neck reconstruction. Clinical use of the flap is ongoing and will be subsequently reported.


Radiographic studies of the deep superior epigastric artery (DSEA) and its connections within the soft tissues of the abdominal wall were performed in 64 fresh cadavers. The patterns of anastomosis between the deep superior epigastric artery and the deep inferior epigastric artery (DIEA) were noted. Type I (29%) revealed a single deep superior epigastric artery and deep inferior epigastric artery, type II (57%) revealed a double-branched system of each vessel, and type III (14%) revealed a system of three or more major branches. In each case, the two systems were united by choke vessels in the segment of muscle above the umbilicus. The supply to the various transverse and vertical skin flaps from the deep superior epigastric artery was defined as a series of captured anatomic territories bounded by choke vessels. The upper transverse and vertical flaps had the best supply, and the TRAM flap had the most tenuous supply. Midline crossover occurs predominantly in the subdermal plexus and on the surface of the rectus sheath. Modifications of the design of the TRAM flap, the case for a delay procedure, the wisdom of including a strip of anterior rectus sheath, and the risks of splitting the muscle with respect to its nerve supply and vascular patterns are discussed on an anatomic basis.


Postburn deformities or scar contractures in the head and neck region of children are a challenge with unique problems compared with the rest of the body. Fourteen children presented with neck contractures following burns, and four children required reconstruction following panfacial burn deformities. The authors reported their experience of late-phase secondary burn reconstruction in the head and neck region of these 18 pediatric patients (age range 9 to 17 years) with 22 fasciocutaneous supraclavicular island flaps, including 5 preexpanded flaps. Clinical follow-up 10 to 29 months. High functional and aesthetic requirements could be fulfilled in all patients. Flap complications occurred in 9%, with low donor site morbidity (9%). The fasciocutaneous supraclavicular artery island flap is reliable and safe for immediate or late resurfacing of facial defects and to release cervical contractures. Customized flap design with tissue expansion without the need for microsurgery allows extended indications and optimized skin use, although good texture and color match is generally difficult to achieve in the head and neck region of severely burned children.


Mentosternal contractures represent a surgical challenge because of their exposed location. They require early operative treatment for both functional as well as aesthetic reasons. Careful clinical examination of scar location and traction forces both in the resting and functional moving state, including proper evaluation of the surrounding soft tissue, is essential for exact preoperative planning of the reconstructive
surgical procedure required. In general, the technically most feasible operation is favored, if functional and aesthetic results are good and the postoperative risk of recurrent mentosternal contractures is low. Between 1987 and 1994, 21 patients with cervical, mentosternal and mentothoracic contractures underwent operative procedures at their clinic. Eight patients underwent a surgical reconstruction with local flaps, and 13 patients received a free microvascularized flap.


Mentosternal contractures are a surgical challenge to the plastic and reconstructive surgeon. The authors added the supraclavicular artery island flap to their armamentarium of surgical procedures to improve the function and cosmesis of disfigured patients. Since July 1994, they have used the supraclavicular artery island flap for releasing postburn mentosternal contractures in eight patients. The flap was planned to be 4 to 10 cm in width and 20 to 30 cm in length with the supraclavicular vessels running axially. All donor defects could be closed primarily without significant postoperative complications in seven of the eight patients. All flaps healed primarily, achieving a good functional result by complete removal of contracting scar tissue for all patients one donor site healed by secondary intention. The authors found the supraclavicular artery island flap both reliable and safe for immediate resurfacing after resection of cervical scars. The anatomy, operative procedure, and postoperative results of the supraclavicular artery island flap were outlined.


Reconstructive procedures in the head and neck region use a wide range of flaps for defect closure. The methods range from local, mostly myocutaneous flaps and skin grafts to free microsurgical flaps. To ensure a satisfactory functional and aesthetic result, good texture and color of the flap are always essential. Moreover, the donor site defect needs to be reduced, with no resulting functional or aesthetic impairment. The authors have found that the shoulder is a region providing an optimal skin texture match to the neck and face. In cadaver dissection, a vascular pedicle extending from the transversal cervical artery with two accompanying veins was found to vascularize a defined region around the shoulder cap. In line with these findings, the previously described fasciocutaneous island flap, nourished by the supraclavicular artery, was developed further and used purely as a subcutaneously tunneled island flap. The tunneling maneuver significantly improves the donor site by reducing scarring. The flap is characterized by a long subcutaneous pedicle of up to 20 cm. The pivot point is in the supraclavicular region and allows the flap to be used in the upper chest, neck, chin, and cheek. The authors introduced the anatomic features and presented clinical cases underlining the surgical possibilities of the flap in reconstructive procedures with expanded indications.


The expanded supraclavicular island flap, as described in 1997 by Pallua, is a useful tool for total facial reconstruction, providing satisfactory results without microsurgical prefabrication. The authors reported the use of this technique in 12 patients requiring large flaps who presented with extensive facial scarring that had been previously reconstructed using disfiguring, pigmented skin grafts. On the basis of their anatomical dissection studies and knowledge of the constant anatomy of the supraclavicular artery and two draining veins, the authors carefully inserted tissue expanders under the supraclavicular island flaps. After the flaps were expanded, all scars were removed and the covering flaps were transferred into place. Sixteen preeexpanded supraclavicular island flaps were used in 11 patients. There were no complications. The authors presented a method of facial reconstruction that has the advantages of creating a large amount of thin tissue of both good color and texture, without the disadvantages of donor site morbidity, lengthy operative time, and high cost. In their opinion, this is the method of choice for total facial reconstruction.
Parts of the face and neck are often affected by thermal damage, which results in particularly disfiguring scars. Movement of the facial muscles is severely impaired, and symmetry as well as facial contours are distorted by scarred skin, which is always of lesser quality. Particular problems arise when the trauma results in partial loss of facial structures such as the nose, lips, or eyebrows. Plastic surgical treatment of burned areas requires thorough knowledge of various procedures for best possible rehabilitation. Burn scars of the facial and neck region were treated by using local flaps and free skin transplantation or combination of both. The indication for the various methods was discussed and demonstrated in their cases.

Flap prefabrication and prelamination are evolving new techniques that are useful in reconstructing complex defects of the head and neck. Flap prefabrication involves the introduction of a new blood supply by means of a vascular pedicle transfer into a volume of tissue. After a period of neovascularization, this volume of tissue may be transferred, based only on its implanted vascular pedicle. The transfer may be a local transposition or by microsurgical transfer. Flap prelamination refers to a technique in which additional tissue is added to an existing flap (without manipulation of its axial blood supply) to make a multilayered flap that may be used for complex, three-dimensional, multilayered reconstructions. This technique may be used locally or at a distance, requiring microvascular transfer. Examples of each were described in this article.

Tissue neovascularized by implanting a vascular pedicle can be transferred as a “prefabricated flap” based on the blood flow through the implanted pedicle. This technique potentially allows any defined tissue volume to be transferred to any specified recipient site, greatly expanding the armamentarium of reconstructive options. The authors prefabricated 17 flaps, and 15 flaps were transferred successfully in 12 patients. Tissue expanders were used as an aid in 11 flaps. Seven flaps were prefabricated at a distant site and later transferred using microsurgical techniques. Ten flaps were prefabricated near the recipient site by either transposition of a local vascular pedicle or the microvascular transfer of a distant vascular pedicle. The prefabricated flaps were subsequently transferred as island pedicle flaps. These local vascular pedicles can be reused to transfer additional neovascularized tissues. Common pedicles used for neovascularization included the descending branch of the lateral femoral circumflex, superficial temporal, radial, and thoracodorsal pedicles. Most flaps developed transient venous congestion that resolved in 36 to 48 hours. Venous congestion could be reduced by incorporating a native superficial vein into the design of the flap or by extending the prefabrication time from 6 weeks to several months. Placing a Gore-Tex sleeve around the proximal pedicle allowed for much easier pedicle dissection at the time of transfer. Prefabricated flaps allow the transfer of moderate-sized units of thin tissue to recipient sites throughout the body. They have been particularly useful in patients recovering from extensive burn injury on whom thin donor sites are limited.


Twenty-one mastoid-occiput–based shoulder flaps were used to reconstruct defects in patients with head and neck cancer. When the tip of the flap does not extend beyond the midclavicle, this flap can safely be elevated and transferred into its final position without delay procedures. Because it does not require secondary sectioning and implantation, the Mütter flap can successfully be used to reconstruct multiple defects within its arch. Its utility thus rivals the more commonly used medially based deltopectoral flap and forehead flap.


Although highly specialized burn centers have significantly reduced mortality rates following extensive total body surface area burns, survivors are often left with grotesque facial disfigurement. The strategy of modern facial restoration emphasizes enhancement of appearance as significantly as mitigation of
functional impairment. Criteria for success are (1) an undistracted “normal” look at conversational distance, (2) facial balance and symmetry, (3) distinct aesthetic units fused by inconspicuous scars, (4) “doughy” skin texture appropriate for corrective makeup, and (5) dynamic facial expression. The author successfully restored 17 severely disfigured burned faces by replacement of entire aesthetic units with microvascular “prepatterned” composite flaps blended into the facial canvas by cosmetic camouflage techniques. Important to outcome is extensive initial intraoperative sculpting to simulate normal planes and contours. Scars are placed at junctions of facial components. Three-dimensional imaging is used to assess architectural asymmetries, and bone grafts are aided by computer-generated acrylic models. Adjunctive procedures include tensor fascia lata slings, intraoperative tissue expansion, suction-assisted lipectomy, and scar management. Flesh-colored makeup and/or tattooing of beard, lips, scars, and eyebrows help to hide scars and pigment the skin to harmonize with the rest of the face. In all cases, facial integrity has been aesthetically restored and, in most instances, with makeup, is near normal in social settings at conversational distances. Facial animation is retained and color matches are excellent. One flap was lost early in the series.


Two-dimensional contrast radiography is the current standard for investigating the vascular anatomy of surgical flaps. The microvascular anatomy of the perforator flap, however, is limited conceptually by representation in two dimensions. Static three-dimensional CT angiography enables vascular anatomy to be evaluated in the coronal, axial, and sagittal planes, and dynamic four-dimensional CT angiography allows the vascular filling of a perforator flap to be visualized over short time intervals in three dimensions. An anatomic study was performed using 11 fresh adult cadavers, 4 males and 7 females. Perforator flaps harvested included the anterolateral thigh, deep inferior epigastric perforator, superior gluteal artery perforator, inferior gluteal artery perforator, thoracodorsal artery perforator, anteromedial thigh, and dorsal intercostal artery perforator. Novel techniques for acquiring both static and dynamic three-dimensional images of macrovascular and microvascular perforator flap anatomy using computed tomographic angiography have been described. This methodology has also allowed the sequential investigation of adjacent vascular territories. This can provide a better understanding of how perforator flaps and the skin are perfused and may aid in the future design of new flaps.


The authors investigated the three-dimensional and four-dimensional arterial vascular territory of a single perforator, termed a “perforasome,” in major clinically relevant areas of the body. A vascular anatomy study was performed using 40 fresh cadavers. A total of 217 flaps and arterial perforasomes were studied. Perforator flaps on the anterior trunk, posterior trunk, and extremities were studied. Flaps underwent both static (three-dimensional) and dynamic (four-dimensional) CT angiography to better assess vascular anatomy, flow characteristics, and the contribution of both the subdermal plexus and fascia to flap perfusion. The perfusion and vascular territory of perforators is highly complex and variable. Each perforasome is linked with adjacent perforasomes by means of two main mechanisms that include both direct and indirect linking vessels. Vascular axis follows the axiality of linking vessels. Mass vascularity of a perforator found adjacent to an articulation is directed away from that same articulation, whereas perforators found at a midpoint between two articulations, or midpoint in the trunk, have a multidirectional flow distribution. Each perforator holds a unique vascular territory (perforasome). Perforator vascular supply is highly complex and follows some common guidelines. Direct and indirect linking vessels play a critical part in perforator flap perfusion, and every clinically significant perforator has the potential to become either a pedicle or free perforator flap.


The vascular anatomy of the thoracodorsal artery perforator flap, which had not previously been elucidated, was examined using three- and four-dimensional computed tomographic angiography.
Twenty-five thoracodorsal artery perforator flaps were harvested from fresh cadavers from the Western population. Dynamic static CT angiography using iodinated contrast media was performed after cannulation of the largest perforator from the descending branch of the thoracodorsal artery and its vena comitans in 10 flaps. Imaging was repeated subsequent to flap thinning between the deep and superficial adipose layers. Colored latex injections and flap dissections were performed in a further 15 flaps to establish the location, caliber, and intramuscular length of the thoracodorsal artery perforators. Two distinct perforator complex types were described. Flap thinning can be safely performed between the deep and superficial adipose layers without significantly affecting flap vascularity, provided that a safety zone about the perforator is respected. The superficial venous system consisted of large veins arranged in a polygonal pattern situated at the subdermal level and was connected to the deep system by the vena comitantes of the thoracodorsal artery perforators. Perforators from the descending branch of the thoracodorsal artery were found in reliable locations. Using a novel dynamic three-dimensional imaging technique, perfusion of the arterial and venous system of the thoracodorsal artery perforator flap was elucidated. Although the flap is inherently thin, it can be safely thinned between the superficial and deep adipose layers.


The authors presented a detailed three- and four-dimensional appraisal of the arterial and venous anatomy and perfusion of the anterolateral thigh flap using a novel computed tomographic technique. Eighteen anterolateral thigh flaps harvested from fresh Western cadavers were used. Four-dimensional CT angiography with injection of iodinated contrast medium into isolated perforators and their vena comitantes was used to investigate the arterial and venous anatomy and flap perfusion. Additional perforators were injected to investigate the vascular connections within the flap. Changes in flap perfusion after thinning and adipofascial flap harvest were also examined, and contrast density within each flap plexus with respect to the perforator was examined. Large-diameter linking vessels at the suprafascial level enabled perfusion of adjacent vascular territories and of the subdermal plexus between angiotomes. Thinning reduced the size of the vascular territory by ligating recurrent vessels at the level of the suprafascial plexus. Adipofascial flap harvest prevented perfusion of the recurrent vessels, demonstrating the role of the subdermal plexus in recurrent flow. Three distinct perforator complex patterns were found with relevance to flap thinning. A superficial venous system perfused the vena comitantes of the descending branch of the lateral femoral circumflex artery and the long saphenous vein. A reduction in vascular territory occurs in the anterolateral thigh flap after thinning and is attributable to ligation of vessels within the suprafascial plexus. Recurrent flow through the subdermal plexus was seen dynamically for the first time and appears to be an important mechanism for skin perfusion.


Harvesting of a forearm flap based on the radial artery has been thought to cause functional or circulatory problems in the donor hand. Eighteen patients were examined three to 24 months after a radial forearm flap had been raised. The function of both hands was studied for grip strength, mobility of the wrist and elbow joints, and sensitivity of the area served by the superficial radial nerve. The patients were interviewed and the cosmetic result was evaluated. Duplex ultrasonography and color Doppler ultrasonography of both ulnar arteries were done, and the brachial arteries were measured as controls. Angle-corrected peak flow velocity (cm/s) in the ulnar artery of the donor forearm was significantly increased at the level of the wrist compared with the control forearm, as was the ulnar-brachial peak flow velocity ratio. The grip strength of the donor hand was weaker by 11.9%. Ten (56%) had areas of sensory loss over the radial nerve distribution, and 7 of the 18 patients complained of cold intolerance. Four patients considered the donor site result so bad that they would not have chosen the operation had they known what the result would look like. The radial forearm flap donor site is not without problems, and the patients must be carefully selected and properly informed preoperatively.

The blood supply to the skin and underlying tissues was investigated by ink injection studies, dissection, perforator mapping, and radiographic analysis of fresh cadavers and isolated limbs. The results were correlated with previous regional studies. The blood supply was shown to be a continuous three-dimensional network of vessels not only in the skin but also in all tissue layers. The anatomic territory of a source artery in the skin and deep tissues was found to correspond in most cases, giving rise to the angiosome concept. Arteries closely follow the connective tissue framework of the body. The primary supply to the skin is by direct cutaneous arteries which vary in caliber, length and density in different regions. This primary supply is reinforced by numerous small indirect vessels, which are “spent” terminal branches of arteries supplying the deep tissues. An average of 374 major perforators was plotted in each subject, revealing that there are still many more potential skin flaps. Their arterial roadmap of the body provides the basis for the logical planning of incisions and flaps. The angiosomes defined the tissues available for composite transfer.


The authors designed a technique for prefabrication of large flaps to cover the whole face reconstruction for cervicocephalic postburn scarring. Aesthetic improvement and a better quality of life was achieved in seven patients.


The supraclavicular flap is used to cover chin and neck region defects. Its main vascular supply is the supraclavicular artery, and it can be harvested as either a skin pedicled flap or an island flap (vascular pedicled flap). The island flap has a wide rotation arc, and both the color and texture match are better for reconstructing contour-sensitive areas such as the chin and neck than those of free flaps harvested from distant sites. The authors used 32 supraclavicular flaps for reconstructions in 30 patients. If circumstances demanded it, they transferred the flaps through skin tunnels to reduce continuous scar formation between the donor and recipient sites. Twenty-eight of the 32 flaps survived completely, but there were 3 cases of distal necrosis and 1 case of 90% necrosis. Twenty-nine of the 30 patients were satisfied with both the functional and aesthetic results. The benefits of the supraclavicular island flap are clear: it is thin but reliable, and easy to harvest.


Despite the fact that arterialized venous flaps provide thin, good-quality tissue to repair defects of the face and neck, their clinical applications have been limited by an unstable postoperative course and variable flap necrosis. To resolve these problems, the authors applied a tissue-expansion technique to the arterialized venous flap before flap transfer. Three preexpanded arterialized venous free flaps were used to treat postburn scar contracture of the cervicofacial region. The donor site was confined to the forearm. A rectangular expander was usually placed over the fascia of the flexor muscles in the proximal two thirds of the forearm. The mean expansion period, volume, and flap size were 44 days, 420 cm³, and 147 cm², respectively. There were no complications. The cervicofacial region was successfully reconstructed after excision of the postburn contractures with preexpanded arterialized venous flaps, with no marginal necrosis or postoperative instability. Large, thin, arterialized venous flaps are well matched with the recipient defect in the cervicofacial area, and the color and texture match obtained with forearm tissue produced an aesthetically favorable result. Preexpanded arterialized venous flaps are another new option for free flap reconstruction of the face and neck.


A reconstruction of a neck with a defect caused by radionecrosis sequelae using two rotation-advancement platysma myocutaneous flaps was presented. The thinness of the flaps, their accessibility, the lack of bulk, and the primary closure of the donor site, without functional or aesthetic problems, all render this technique an attractive option for replacing anterior neck skin.
Chapter 7

Posterior Trunk

The posterior trunk is a paradox in that it offers some of the largest soft tissue donor sites of the body while presenting some of the most difficult reconstructive challenges. The latissimus is one of the most versatile and widely used flaps in reconstructive surgery and can be used for almost any area in the body. The gluteal area also provides an abundance of options for reconstruction of decubiti, vaginal reconstruction, and breast reconstruction. Difficult wounds in the midline and lower back can be reconstructed with trapezius, paraspinous, lumbar perforator, and gluteal-based flaps. Although these reconstructive challenges are not common, it is important to know about the flaps required in this area because there are few options available for solving these complex problems.

Gluteus Maximus and IGAP/SGAP Flaps
Gluteal Thigh Flap
Scapular/Parascapular Flap
Lumbar Perforator Flap
Trapezius Flap
Latissimus Dorsi Flap
Paraspinous Flap
ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>A rhomboid-shaped muscle. Important landmarks for locating the muscle include the posterior superior iliac spine (PSIS), the tip of the coccyx, the ischial tuberosity, and the iliotibial tract.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>$24 \times 24$ cm. The skin paddle design is variable, depending on the patient. A flap $22$ cm long and $10$ cm wide allows primary closure.</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>The gluteus maximus originates from the PSIS, the coccyx, and the bony and ligamentous structures of the lateral sacrum.</td>
</tr>
<tr>
<td><strong>Insertion</strong></td>
<td>Insertion into the greater trochanter and the iliotibial tract of the fascia lata.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>The gluteus maximus extends and rotates the thigh laterally.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Muscle-only, myocutaneous, or skin only.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type III.</td>
</tr>
<tr>
<td><strong>Dominant Pedicles</strong></td>
<td>Superior gluteal artery, inferior gluteal artery.</td>
</tr>
<tr>
<td><strong>Minor Pedicle</strong></td>
<td>First perforator of profunda femoris artery.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td><em>Motor:</em> Inferior gluteal nerve (L5 to S2). <em>Sensory:</em> Posterior divisions of S1 to S3 medially, posterior divisions of L1 to L3 laterally.</td>
</tr>
</tbody>
</table>
Section 7A

POSTERIOR TRUNK

Gluteus Maximus
and IGAP/SGAP Flaps

CLINICAL APPLICATIONS

Regional Use
- Sacrum
- Ischium
- Trochanter

Distant Use
- Breast

Specialized Use
- Anal sphincter
- Meningomyelocele
- Breast
ANATOMY OF THE GLUTEUS MAXIMUS AND IGAP/SGAP FLAPS

Bony landmarks of gluteus muscle

Undersurface of muscle with neurovascular anatomy

**Fig. 7A-1**

**Dominant pedicles:** Superior gluteal artery; inferior gluteal artery
ANATOMY

Landmarks
A line drawn from the PSIS to the tip of the coccyx marks the posterior border and origin of the gluteus maximus muscle. A second line drawn from the tip of the coccyx through the inferior edge of the ischial tuberosity to the iliotibial tract indicates the inferiormost extent of the gluteus muscle. A line drawn through the posterior superior iliac spine parallel to the inferior border of the muscle denotes the superior border of the muscle. Laterally, the border of the muscle is at the greater trochanter and it extends inferiorly into the iliotibial tract. The muscle is rhomboid shaped.

Composition
A gluteus maximus flap provides a muscle-only flap, a myocutaneous flap, or a perforator flap containing overlying skin and fat only.

Size
The size of the gluteus maximus muscle in its entirety is $24 \times 24$ cm. The skin paddle design is variable, depending on the patient, and may be as long as 22 cm, with a width of 10 cm. Primary closure is possible.

Origin
The gluteus maximus muscle originates from the PSIS, the coccyx, and the bony and ligamentous structures of the lateral sacrum.

Insertion
The insertion of the muscle is into the greater trochanter and the iliotibial tract of the fascia lata.

Function
The gluteus maximus extends and rotates the thigh laterally. It is important in running, jumping, standing, and climbing; thus it is not taken in its entirety when used for reconstruction in an ambulatory patient. Up to half of the muscle can be taken with minimal impact on function.

Arterial Anatomy (Type III)

Dominant Pedicle  

Superior gluteal artery

Regional Source  
Internal iliac artery.

Length 3 cm.

Diameter 2.5 mm.

Location Deep to muscle origin above the piriformis.

Dominant Pedicle  

Inferior gluteal artery

Regional Source  
Internal iliac artery.

Length 3 cm.

Diameter 2.5 mm.

Location Deep to muscle origin below the piriformis.

Minor Pedicle  
First perforator of profunda femoris artery and venae comitantes

Regional Source  
Profunda femoris artery.

Length 1 cm.

Diameter 0.6 mm.

Location Below inferior muscle insertion.

The superior and inferior gluteal arteries communicate with transverse branches of the medial femoral circumflex artery, lateral femoral circumflex artery, and the first perforator of the profunda femoris artery. None of these minor pedicles alone is sufficient to carry or supply the flap.

Venous Anatomy

The superior and inferior gluteal veins are 2 to 4 mm in diameter, with the superior vein often larger than the inferior vein. At the level of the piriformis muscle, the venae comitantes have often combined into a single vein, with an effective usable length of 3 cm.
Nerve Supply

**Motor**
The inferior gluteal nerve (L5 to S2) emerges from the sciatic foramen and runs below the piriformis muscle, entering the gluteus maximus muscle from its deep surface. The inferior gluteal nerve supplies motor innervation to both the superior and inferior portions of the muscle.

**Sensory**
The skin territory of the gluteus maximus muscle is supplied by the posterior divisions of S1 to S3 medially and the posterior divisions of L1 to L3 laterally. This innervation cannot be maintained for island flaps and free flaps.

**Vascular Anatomy of the Gluteus Maximus and IGAP/SGAP Flaps**

Fig. 7A-2

**Dominant pedicles:** Superior gluteal artery (D1); inferior gluteal artery (D2)

**Minor pedicle:** Profunda femoris perforator (m1)

p, Piriformis
FLAP HARVEST

Design and Markings

When possible, it is best to mark the patient in a standing position; the marks should then be confirmed with the patient prone or in a lateral position. The superior gluteal flap is most commonly used in a V-Y fashion, or as a perforator flap. As a perforator flap, the skin paddle design is similar to that for a buttock lift. The inferior gluteus–based flap is also used in a V-Y fashion. Inferior–based flaps using a skin paddle are carefully designed so that the aesthetic of the lower buttock is maintained after harvest.

Fig. 7A-3 Variations of skin paddle design for the gluteal flap.
When a muscle-only rotation flap is used, access incisions are made directly over the desired portion of the muscle, or the muscle can be accessed through the nearby defect. When using the inferior portion of the gluteal muscle to create an anal sphincter, access incisions are directly over the muscle and are kept above the gluteal fold for best cosmesis.

**Patient Positioning**

For surgery on sacral, trochanteric, or ischial soft tissue wounds, prone positioning is best. For creating an anal sphincter, a jackknife prone position is preferable. Unilateral breast reconstruction may be performed with the patient in a lateral decubitus position for both harvest and inset. Many surgeons prefer to transfer the patient from supine (for mastectomy and/or recipient vessel preparation) to prone (for gluteal flap harvest), then supine again (for inset of the flap). Bilateral flap harvest for bilateral breast reconstruction has been described.

![Fig. 7A-4](image)

**Fig. 7A-4** Lateral decubitus positioning is used for simultaneous immediate breast reconstruction. **A**, A bean bag is used in combination with an axillary roll and padding of all pressure points. **B**, The arm is draped free, and care is taken during surgery to avoid unnatural positions.
GUIDE TO FLAP DISSECTION

Standard V-Y Advancement Flap

After marking the skin paddle that overlies the gluteus maximus muscle, the surgeon incises the skin as marked down to the muscle fascia. Dissection proceeds from lateral to medial, with division of the muscle laterally. Access is then gained to the submuscular space, where the underlying piriformis muscle can be found. For advancement toward the midline, the origin of the muscle must be carefully divided along the sacrum, taking care not to injure the superior or inferior gluteal vessels. The flap is based off the superior vessel or the inferior vessel that supplies that section of muscle being used. Once the muscle has been fully divided around the skin island, it easily advances to the midline. Large defects can often be closed with bilateral advancement flaps (see Fig. 7A-11).

Fig. 7A-5  A, V-Y design for a midline wound. The flap is as wide as the bursa, not the skin defect. B, Advancement is possible by incising the skin down to muscular fascia and dividing the proximal and distal muscle. C, Cadaveric dissection of the superior and inferior gluteal vessels. Either or both can be used to vascularize the flap. D, Flap after inset in V-Y fashion, allowing tension-free closure at the midline.

Dominant pedicles: Superior gluteal artery (D₁); inferior gluteal artery (D₂)
FLAP VARIANTS

- Semicircular advancement flap
- Functional muscle transfer flap
- Superior gluteal artery perforator (SGAP) flap
- Inferior gluteal artery perforator (IGAP) flap
- Myocutaneous free flap

Semicircular Advancement Flap

A large semicircular advancement flap can be designed to take advantage of the excess tissue of the buttock. Undermining of the flap should be limited in the areas of the superior and inferior gluteal perforators. The remainder of the areas may be undermined and advanced medially. Direct closure of this donor site is usually possible, although back-grafting is always an option. It is not necessary to visualize the pedicle in these flaps. For added rotation, the muscle can be divided laterally as the flap is advanced medially (see Figs. 7A-10 and 7A-12).
**Functional Muscle Transfer Flap**

A sigmoid-shaped incision is made over the lower portion of the buttock, exposing the inferior half of the gluteus muscle, which is the most useful for this application. For patients without anal sphincter function, the inferior gluteal muscle will be released laterally at the level of its fascial insertion in the iliotibial band. Some of this fascia is included with the harvest to facilitate inset later. A third to a half of the gluteal muscle is then harvested from lateral to medial; the muscle is split in such a way that the inferior gluteal vessels are included in the flap. The surgeon should note a key dissection point at the posterior femoral cutaneous nerve (PFCN) branches as they exit from the inferior border of the gluteus muscle, accompanying the continuation of the inferior gluteal artery. Care must be taken to preserve the posterior femoral cutaneous nerve to maintain posterior thigh sensation. The nerve and the inferior gluteal vessels can then be directly seen as the muscle dissection proceeds and the muscle is split. Also, the inferior gluteal nerve must be protected; it lies lateral to the sciatic nerve and innervates the entire gluteus muscle. Once the flap has been elevated to the origin of the inferior gluteal vessel at the piriformis, it can be passed through two subcutaneous tunnels, one anterior and one posterior to the anus. They are then anchored to the contralateral ischial tuberosity. Care must be taken to leave soft tissue over the sciatic nerve to prevent irritation postoperatively when the patient is sitting (see Fig. 7A-13).

**Superior Gluteal Artery Perforator Flap**

The superior gluteal artery perforator (SGAP) flap is used most commonly as a free flap but can be used as a rotational flap. The flap is designed on the superior portion of the buttock. One can expect the origin of the superior gluteal vessels to lie on a point a third the distance from the PSIS to the trochanter, and this can be confirmed by a handheld Doppler device. After incision of the skin paddle, dissection proceeds from lateral to medial, elevating the fascia off the gluteus maximus muscle. Once the desired large perforator is encountered, the vessels may be followed with careful intramuscular dissection to the source superior gluteal vessel. Many side branches exist at this level, and the surgeon should invest time in further, sometimes tedious, dissection to maximize the pedicle length or to achieve an adequate length and diameter of vessel to match the recipient site.

**Fig. 7A-7** Identification of anatomic landmarks. A mark at the transition of the proximal and middle third on a dashed line drawn from the posterior superior iliac spine to the greater trochanteric prominence represents the location where the superior gluteal artery exits the pelvis. The line leading from the superior edge of the greater trochanter bisects the line between the PSIS and the tip of the coccyx. This marks the position of the piriformis muscle.
After this has been adequately dissected, the flap can be used as a rotational flap for sacral or gluteal wounds; it may also be harvested as a free tissue transfer (see Figs. 7A-14 and 7A-16 through 7A-18).

**Fig. 7A-8**  A, Design of the SGAP flap. The location of the superior gluteal artery is confirmed by Doppler ultrasonography. B, The flap is elevated in the subfascial plane with identification of the SGAP perforators. C, After inset of the SGAP free flap for breast reconstruction. The superior gluteal vessels have been anastomosed to the internal mammary system.
**Inferior Gluteal Artery Perforator Flap**

After the skin island for the inferior gluteal artery perforator (IGAP) flap is designed, dissection proceeds down to the muscular fascia. On the inferior border of this flap, the posterior femoral cutaneous nerve will be evident with the inferior gluteal artery as it descends down to the thigh. The surgeon should attempt to spare this nerve to avoid numbness of the posterior thigh. The artery will ultimately be divided as dissection of the inferior gluteal artery proceeds through the muscle to its source inferior gluteal system. Again, many side branches exist at this level, and time should be invested in further dissection to maximize the pedicle length and to achieve an adequate diameter of vessel to match the recipient site. Once this has been adequately dissected, the flap can be used as a rotational flap for sacral or gluteal wounds; it may also be harvested as a free tissue transfer. Care must be exercised not to injure the inferior gluteal nerve, which overlies or is lateral to the sciatic nerve and is often in the area of the inferior gluteal artery (see Figs. 7A-15, 7A-19, and 7A-20).

**Myocutaneous Free Flap**

A patch of muscle can be taken that includes these perforators, making them myocutaneous free flaps. **Note:** Inclusion of muscle will severely shorten the pedicle length.

**ARC OF ROTATION**

**Standard Flap**

In a standard muscle flap, the point of rotation is the superior and/or inferior gluteal vessels that will supply the flap. Release of the sacral origin may assist in inset but will not lengthen the arc of rotation.

![Standard arc for total muscle flap](image)

![Arc for inferior gluteal muscle](image)

![Arc for superior gluteal muscle](image)

**Fig. 7A-9**
Transposition Flap
When a flap containing a skin paddle is rotated, the arc of rotation will be limited by its vascular supply (superior and/or inferior gluteal vessels). Arc of rotation can be improved by dissecting the perforators that supply the flap and leaving muscle behind, which effectively lengthens the pedicle (see Figs. 7A-16 and 7A-17).

V-Y Advancement Flap
The flap may be transposed or advanced in a V-Y fashion. Advancement centrally is limited by the origin of the muscle at the lateral edge of the sacrum, so this must be released. Further advancement of the flap may be possible by completely dividing the gluteus maximus lateral to the skin island and pedicle (in nonambulatory patients) or by isolating the flap to either the superior or the inferior vessels, depending on the reconstructive need (see Fig. 7A-11).

FLAP TRANSFER
A standard flap may be transposed through a subcutaneous tunnel or through an access incision—whichever path fits the reconstructive need. V-Y advancement is through direct advancement, with closure of the donor site behind the advanced flap. In functional muscle reconstruction, the inferior flap is split and tunneled subcutaneously both anteriorly and posteriorly around the anus. The harvested fascia on the distal part of the elevated muscle is then attached to the ischial tuberosity on the contralateral side through a counterincision.

FLAP INSET
Pedicle Flap
The pedicle flap should be inset without placing tension on the superior or inferior gluteal pedicle. Closure of the donor site should bear the tension of the closure, leaving the rotated flap tension free.

Transposition and V-Y Flaps
For either a transposition flap or a V-Y flap, closure of the donor site should bear the tension of the closure, leaving the advanced or transposed flap tension free. For inset of a functioning muscle transfer, it is critical to maintain the functional length of the muscle; this is usually not a concern when insetting the muscle to the contralateral ischial tuberosity.

DONOR SITE CLOSURE
For a rotational or V-Y flap, direct donor site closure is recommended, because these wounds are often deep after the flap has been moved. Planning the size of the skin paddle component of the flap is therefore critical in ensuring primary closure of the donor site. A width of 10 cm can usually be closed without difficulty, but this is patient dependent. Wide undermining in a subcutaneous plane can also aid in closure. If needed, back-grafting with a skin graft can be performed in semicircular advancement flaps. Closure of a free flap site is more straightforward, because there is less concern about placing pressure on the pedicle. The deep fascia is often closed as the first layer, followed by skin closure. In general, these wounds are notorious for developing postoperative seromas, and a drain tube should be placed at the time of harvest.
CLINICAL APPLICATIONS
This 72-year-old woman presented with osteoradionecrosis of the sacrum and exposure of the cauda equina after tumor extirpation and radiation therapy. Debridement of bone and necrotic tissues with muscle coverage of the cauda equina and stable skin coverage were required. Options included gluteal muscle flaps, myocutaneous flaps, and free tissue transfer.

Fig. 7A-10  A, The defect is shown with a planned large semicircular skin flap based on the inferior gluteal artery for skin cover. B, The planned superior gluteal muscle transposition based on the superior gluteal artery to cover the exposed cauda equina. The semicircular flap is elevated and the perforator of the IGA has been left intact. C, The defect has been closed after transposition and rotation of the flaps. This combination is acceptable for an ambulatory patient and preserves the contralateral side for complications or future needs. (Case supplied by MRZ.)
This 28-year-old man with paraplegia had a stage 4 sacral decubitus ulcer. After maximizing nutrition and debriding necrotic tissues, options for closure included gluteal-based rotation or transposition flaps. In this case, a myocutaneous flap provided the best padding to guard against future pressure sores.

![Fig. 7A-11](image1)

**A**, The defect and the design for a V-Y advancement flap on the left versus a semicircular flap on the right. Only a V-Y flap was required. Notice that the design of the V-Y is large enough to fill the underlying bursa that is always present. A common error is to focus only on the skin defect and design the flap too small to fill the defect, leading to failure. **B**, The wound closed after advancement. This required release of the medial origin of the gluteus and release of the lateral muscle. This maneuver should only be done in nonambulatory patients. The flap should be designed over the entire gluteus muscle so readvancement of the flap is possible if the pressure sore recurs. (Case supplied by MRZ.)

This 54-year-old man with paraplegia presented with a stage 4 sacral decubitus ulcer. For this more superficial wound, a semicircular flap was chosen.

![Fig. 7A-12](image2)

**A**, The flap design, which will spare the IGA perforator but sacrifice the SGA perforator to allow advancement. Note the wide design, which can be readvanced later if the pressure sore recurs. **B**, The flap advanced and closed without tension. A larger design allows easier closure of the donor site which can be cheated closed over a longer distance. (Case supplied by MRZ.)
This 24-year-old woman presented with anal incontinence after an excessive episiotomy and tear from childbirth. On rectal ultrasonography, her sphincter muscle was shown to be incomplete, and she was referred for functional muscle transfer. Although some surgeons use a gracilis muscle wrap for this procedure, the gluteal muscle transfer is preferred. The gracilis has little active function, since the area used is mainly tendinous. The wrapping of the sphincter is likely bringing the remaining functional muscle into a better position to function. A gluteal transfer has the same effect, plus a shutter effect, with active contraction of the gluteus, a natural inclination when trying to maintain continence.

Fig. 7A-13  A, The flap was designed to use the lower third to half of the gluteus muscle; this uses the longest portion of the muscle, which must reach to the contralateral ischial tuberosity. The sigmoidal incision (blue dashed line) provided the best access to the origin and insertion areas of the muscle. Care was taken to keep the incision within the buttock proper. B, The muscle was elevated and split, one tongue to go above and one to go below the anal sphincter. Some fascia was harvested at the insertion site to aid in fixing the muscle after transposition. C, The muscle after transposition. The remaining gluteus effectively covers the exposed sciatic nerve to pad the area and protect against postoperative irritation. D, The result is seen 6 months postoperatively with minimal contour deformity; the patient has normal continence. (Case supplied by MRZ.)
This 48-year-old-woman desired bilateral breast reconstruction with autologous tissue and opted for a bilateral GAP breast reconstruction. She did not have adequate abdominal or thigh tissue for bilateral reconstruction, a common problem necessitating the use of breast implants.

Fig. 7A-14  A, The patient had thin skin cover, with visible ribs and inverted-T scars from her previous breast reduction surgery. B and C, Design of the SGAP flap. Note that this patient’s excess fat lies superiorly, favoring an SGAP over an IGAP design. Her reconstruction was performed one side at a time, separated by 4 months.
Fig. 7A-14  D-G, The final result 1 year after revision. The inverted-T scars required vertical inset of the flaps, improving their projection and shape. The Z-plasty seen on the right breast is a useful maneuver for rounding off a step-off deformity. H, Donor scars at 1 year postoperatively. (Case supplied by MRZ.)
This 24-year-old woman was diagnosed with infiltrating intraductal carcinoma of her left breast. She wanted a breast reconstruction to match her unmodified opposite breast. Although her lower abdomen was thin, scarred, and had been irradiated, she did not want a back scar, so free flap reconstruction with the inferior gluteus flap was selected.

Fig. 7A-15  A-C, Preoperative markings delineate the extent of the dissection. The mastectomy scar was to be opened and the gluteus flap inset. Markings include the skin island and the fat harvest. D, A section of the inferior gluteus pedicle was extended proximally to ensure adequate pedicle length. E and F, The free inferior gluteus flap was divided and prepared for anastomosis. The flap was inset with minimal trimming to provide the best symmetry with the contralateral breast.
G and I, The patient is shown preoperatively and H and J, 18 months later, after flap thinning and nipple-areolar reconstruction. Her breast symmetry and softness are acceptable. K and L, Preoperative and postoperative views of the donor site show the scar in the right buttock crease. Liposuction of her opposite hip was performed at the time of nipple reconstruction. (Case supplied by GJ.)
This 48-year-old ambulatory patient was referred with a chronic wound of the sacral region. Four years earlier, the patient had undergone a sigmoidectomy for adenocarcinoma. The patient had received adjuvant radiation to the pelvic/gluteal area and had developed a fistula, which necessitated a temporary stoma. The patient then underwent radical debridement, which included resection of part of the coccyx. Two previous attempts to close the wound primarily had failed because of chronic infection and the presence of irradiated tissue. Clinical examination revealed a 3 by 5 cm chronic wound, extending deeply in the sacral region. After radiologic and histologic investigation, no locoregional recurrence of disease was evident. A wide debridement was performed and a pedicled SGAP flap was designed.

**Fig. 7A-16**  
A, A 3 by 5 cm necrotic wound over the sacral area. B, Harvesting a pedicled SGAP flap based on one perforator. C, The medial part of the flap was deepithelialized and used to fill the depth of the wound. D, The reconstructed result is seen; function has not been hindered in this ambulatory patient. (Case courtesy Phillip N. Blondeel, MD.)
The neonate shown below was born with an undiagnosed myelomeningocele. Plastic surgical consultation was obtained to assist with soft tissue closure. Because of the defect size and location, alternative options to standard closure techniques were devised. We decided that vascularized tissue directly over the neural tube closure would minimize both cerebrospinal fluid leaks and the risk of infection. An SGAP flap was designed and rotated based on large medial perforators, maximizing vascularized skin transfer and minimizing muscle damage.

**Fig. 7A-17**  
A, The flap and perforators are marked.  
B, The flap was elevated on the medial perforator with a small muscle cuff around the perforator.  
C, The flap was tunneled and ready for inset.  
D, One year postoperatively, the closure is stable, and there is minimal donor site scarring. (Case courtesy Phillip N. Blondeel, MD.)
This 54-year-old woman had undergone failed breast implant reconstructions; she also had a history of an emergency cesarean section via a midline incision.

Fig. 7A-18  A, The patient did not have enough abdominal volume to achieve the C cup breasts she desired. B, However, her buttocks were ample for creating two C cup breasts. C, A bilateral SGAP breast reconstruction was performed. D and E, The donor sites retain acceptable contour after harvest of the flaps. (Case courtesy Joshua L. Levine, MD.)
This 47-year-old woman presented with lobular carcinoma in situ of the right breast and atypical ductal hyperplasia. Multiple negative biopsies had yielded negative results, but she opted for bilateral mastectomies. For the reconstruction, she requested larger breasts than her A cup size.

Fig. 7A-19  A, The patient did not have enough abdominal tissue to create two larger breasts. B, She had ample fat in the inferior buttock area for reconstruction and was an excellent candidate for IGAP flap reconstruction. C, She is shown after bilateral mastectomies and IGAP breast reconstruction. D, Note the improved buttock contour in the donor sites. (Case courtesy Joshua L. Levine, MD.)
This 36-year-old woman presented for bilateral nipple-sparing prophylactic mastectomy. She did not want a scar on her abdomen.

**Fig. 7A-20**  
A, The patient is shown preoperatively. B, Bilateral IGAP flaps were designed and harvested. C, Bilateral nipple-sparing mastectomies were performed, with IGAP reconstruction of her breasts. D, Note that donor site scars lie in the inferior buttock creases, and with the IGAP flap, there is no flattening in the upper buttock. (Case courtesy Joshua L. Levine, MD.)
Pearls and Pitfalls

- Use of the gluteus maximus muscle should be a distant second or third choice for reconstruction in an ambulatory patient. The patient may have no difficulty ambulating with harvest of up to 50% of the muscle, but the possibility of nerve injury or functional disability does exist. A gluteal perforator flap should be considered.

- One should favor the superior gluteal vessel when planning flap rotations, advancements, or free flaps. This particular dissection does not put the inferior gluteal nerve or the posterior femoral cutaneous nerve at risk.

- When harvesting a skin paddle, a superior paddle is favored, because this best mimics the tissue that would be removed for a buttock lift. The scar, although thick, elevates the buttock, which is more natural than harvesting the skin from the inferior crease and distorting the crease. This is sometimes more difficult to hide in clothing.

- When used for breast reconstruction, the fatty tissue from the gluteal area is not comparable to the fatty tissue one sees in the abdomen. Because of the fibrous nature of the buttock, shaping can be more difficult and matching a natural breast more complex. Z-plasties and fat grafting can be very helpful.

- Anal sphincter reconstruction can be performed using the gluteal muscle; in fact, it is the preferred reconstruction. Contracting the gluteal muscle is a natural response when forcibly contracting the anal sphincter, so it is easier for patients to learn to use this muscle in this fashion.

- It is best to leave drains in place until the patient is fully ambulatory, because this donor site is known for seroma formation, especially after the patient becomes more active. It is not unusual for gluteal drains to remain in place for 2 to 3 weeks.

- It is important to maintain a soft tissue pad over the sciatic nerve when muscle is harvested, or patients may complain of sciatica or pressure-related problems when sitting on this area.

- Treatment of meningomyelocele in children has been described using gluteal flaps, either as a transposition flap or in continuity with advancement of the latissimus and paraspinal muscles (see Fig. 7A-17).
EXPERT COMMENTARY

Joshua L. Levine

The gluteal area has long been an outstanding choice for autologous perforator flap breast reconstruction with gluteal artery perforator (GAP) flaps. An adequate volume of tissue can almost always be found from either the superior (SGAP) or inferior (IGAP) region in patients for whom an abdominal deep inferior epigastric perforator (DIEP) flap may not be the best option.

Indications

The gluteal region should be considered for any patient interested in autologous breast reconstruction. My preference is to use the abdomen as the donor site whenever it is available. However, there are circumstances in which the abdomen is not available, or not the best option. For example, if the patient has had an abdominoplasty, liposuction, or other procedures that render her abdomen unusable, one must look elsewhere for donor tissue. Also, in very thin patients, especially if they undergo bilateral mastectomy, the abdomen may not provide enough volume for two reasonable breast reconstructions. There are situations in which the patient simply does not want a long scar across her front, and would prefer a scar that she will not have to see in the mirror. In these situations, the GAP flaps have the advantage of providing adequate tissue for breast reconstruction, and hiding the scar behind the patient.

Most women who are candidates for a GAP flap breast reconstruction have tissue in both the upper and lower buttock areas, and may choose SGAP or IGAP based on the following advantages and disadvantages: the SGAP scar can be hidden in panties or a swimsuit, but the removal of tissue from the upper buttock creates a flattening that is seldom favorable. The IGAP scar is hidden in the inferior buttock crease and does not flatten the buttock, but it may distort the curve of the infrabuttock crease.

Advantages and Limitations

Technical considerations include the fact that compared with the abdomen, gluteal fat is more spongy and firm. Thus it can be slightly less pliable for shaping in the breast reconstruction. Also, the amount of skin available is less than that for an abdominal flap. This poses some limitations in delayed reconstructions, especially in patients who have had radiation therapy. These issues are minor and can be overcome with proper planning and realistic expectations.

The major limitation is the extreme difficulty of the procedure. Of all the perforator flaps used for breast reconstruction, most experienced surgeons agree that the GAPs are the most challenging. As such, most surgeons offer these procedures only one at a time, so that a staged reconstruction is done for a bilateral procedure, as described in this chapter. Bilateral simultaneous GAP flap breast reconstruction has been described (by me and others). It requires two expert microsurgeons harvesting the buttock flaps simultaneously, preferably at the same rate, and intraoperative repositioning of the patient twice.

Anatomic Considerations

When dissecting the perforator through the muscle, branches to surrounding muscle are divided as the pedicle is followed down into the muscle. The branches, especially the veins, get bigger as the dissection continues. Before reaching the superior gluteal vessels (in the SGAP), a thick layer of posterior gluteal fascia is encountered (Fig. 7A–21).
At this level the branches become very large and cumbersome. The fascia must be opened widely to fully address this area, which had been called the *Medusa’s head*. This fascial layer does not exist in an IGAP dissection. If one is able to get beyond this obstacle, the reward is the gluteal artery, which is very large in diameter (2 to 4 mm), and makes for a much easier arterial anastomosis. *If the flap is harvested too soon, the artery will be a poor size match for the internal mammary artery.* In harvesting an IGAP flap the dissection is very similar, but the length of the perforator is usually much greater. It may take longer to get to an artery of adequate diameter. The posterior femoral cutaneous nerve may or may not be encountered. If it is encountered, it is separated from the artery and preserved. The sciatic nerve is not encountered.

**Personal Experience and Insights**

GAP flaps take a great deal of effort and stamina to perform successfully. I have found preoperative MRA imaging to help enormously in hastening the procedure and reducing anxiety. Knowing where the best perforator is and its course through the muscle helps one to plan the best incision and dissection. Persistence and patience at the “Medusa’s head” is also of paramount importance. The veins are very large and thin walled, and the operative space is deep and tight. The farther the dissection is carried, the better caliber the artery will be, but it must be done with extreme caution.

**Recommendations**

**Planning**

Preoperative MRA imaging was introduced by my group in 2005. We were impressed by the images from CT angiography from the group in Barcelona and wanted to obtain the information without radiation. We have fine-tuned the technique over the years to the point at which we are consistently getting extremely useful information. I highly recommend preoperative imaging. I also always mark the patient the day before the procedure in my office. This gives me the opportunity to plan and think about the details of the procedure. I find this very helpful.

*Continued*
**Technique**

The entire flap is incised through the skin and subcutaneous fat. At this point it is very important to bevel as the dissection goes through the fat, so that more fat volume is captured, if needed (Fig. 7A-22).

![Fig. 7A-22](image)

**Fig. 7A-22** Beveling to improve the volume harvest in an SGAP flap.

Once the skin is opened, the flap is mobile, so the position of the marked Doppler signal may change with respect to its position as it emerges from the muscle. *Always be aware of the original vessel position with respect to all landmarks.* The flap can be elevated off the muscle from any side in a subfascial plane. The most important element is to do so parallel to the muscle bundles. Each bundle should be completely uncovered within the field before moving to the next bundle. This makes for a very neat and predictable dissection, so that the perforators are very visible when they emerge within the septum between two bundles (Fig. 7A-23).

![Fig. 7A-23](image)

**Fig. 7A-23** This photo emphasizes the importance of dissecting parallel to muscle bundles so that perforators (arrow) can be visualized as they emerge.
At that point the septum is opened all the way to the extent of the operative field. These recommendations are consistent with the surgical principal of “don’t get in a hole.” This will be a deep dissection, and it is very important to open the field as wide as possible. I use the Ellman bipolar forceps and a micro-DeBakey forceps for the entire dissection. Small muscle branches are cauterized with the bipolar cautery, and larger ones are tied. Clips are not used because they can fall off and/or get in the way during microanastomosis. Clips are used for the final vessel harvest. Great care must be taken to avoid injury to a giant vein when the dissection is deep in the muscle.

**Postoperative Care**
The patient is placed in compressive garments and a supportive bra. The Foley catheter is removed on first day. She is out of bed and ambulating on postoperative day 1. The patient can shower on day 3 and is discharged on day 4.

**Complications: Avoidance and Treatment**
If the SGAP pedicle is too short (less than 6 cm), more length can be achieved on the internal mammary vessels by removing a rib. Buttock drains are left in place for approximately 2 weeks, or until the drainage diminishes. Recontouring procedures should be expected with SGAP reconstruction, including fat injection, liposuction, or local flap procedures to improve upper buttock volume deficiency.

**Take-Away Message**
GAP flap reconstruction is a challenging procedure. Careful planning, skill, and patience are important.

**EXPERT COMMENTARY**
Michael R. Zenn

**Indications**

**Decubitus Surgery**
The gluteal area is the main source of reconstructive tissue for the treatment of sacral wounds, mainly decubiti. Most reconstructive surgeons are comfortable transferring these tissues either as a V-Y or as a semicircular advancement flap. The location of the pedicles (SGA and IGA) is favorable because they are close to the defect to be reconstructed, facilitating ease of transfer. My preference is to use the V-Y flap and design it large; these decubitus patients are “patients for life,” because the decubiti will recur. The V-Y design can be reelevated and advanced when the sacral ulcer reappears. The further extension of this logic is to not use the gluteal tissues for other wounds, such as ischial and trochanteric decubiti. These should be reconstructed with other flaps (ischial: biceps, gracilis; trochanteric: tensor fascia lata), because these patients will someday present with a sacral decubitus, and the surgeon will want the gluteal tissues to be available. Use of the island perforator flaps can be helpful in cases in which bulk is not needed. These cases also provide valuable practice for SGAP and IGAP free flap cases.
Anal Incontinence Surgery
The use of the gluteal muscle for anal incontinence was a dramatic change in my practice from the more standard use of the gracilis. I think that in these cases, some of the sphincter muscle may still exist, and the gracilis tendon wrapping around the sphincter was less about adding a functional muscle to the sphincter; rather, it decreased the lumen size and brought what little functional muscle that existed into better apposition. The motion of adducting the knee for sphincter control is not natural and transfers poorly. I have had great success with the gluteal transfer, especially in young women with a birthing injury that has resulted in fecal incontinence. The muscle is functional, acting as a shutter mechanism that promotes continence. The act of flexing the gluteus muscle while attempting sphincter control is a natural one. The surgical procedure, with diet modification, has been life changing for these patients.

Breast Reconstruction
Gluteal tissue for distant transfers is used mainly for breast reconstruction, and this is admittedly a second or third option. The reason for this is threefold: (1) the patient positioning or required position change is awkward, (2) the dissection is difficult, and (3) the fibrous nature of buttock fat makes it harder to shape than other tissues. In immediate breast reconstruction, lateral positioning allows a two-team approach and saves time, but a position change to supine is still often required for definitive flap inset. For delayed reconstruction, I now always use supine positioning for recipient vessel identification, prone positioning for flap harvest and closure, and return the patient to the supine position for microscopic anastomoses and flap inset. As I have matured as a microsurgeon, I feel more comfortable delaying the revascularization of these cutaneous flaps for up to an hour during donor site closure. I have never seen a problem with thrombosis or necrosis as a result of this.

I only perform one side at a time in bilateral cases, separated by 4 months minimum, but some surgeons perform bilateral GAP flaps at the same time, using the supine-prone-supine sequence and a two-team simultaneous approach. Although the dissection may be the hardest of all possible choices, experience and repetition are essential to making the surgery more acceptable.

Take-Away Messages
The gluteal area is valuable for reconstruction of many difficult problems. Each application requires excellent planning, execution, and attention to detail to accomplish the reconstructive goal and minimize morbidity in an area critical to the patient’s activities of daily living.
Bibliography With Key Annotations


The authors described a modification of the classic gluteal bilateral V-Y advancement flap for sacral defect closure. After initial debridement, the V-Y design is marked on both sides of the defect. The incision is carried down to the fascia of the underlying gluteus maximus muscle. The upper and lower arms of the flaps are elevated and advanced on the gluteal muscle toward the midline, interdigitating each opposing arm. The overall result is a zigzag, broken midline suture. This procedure was carried out in 14 patients with sacral pressure sores and in 1 patient with a chronic pilonidal sinus. All flaps survived without major problems. There were no recurrences during the 6 to 16 months of follow-up. The interdigitating fasciocutaneous V-Y gluteal flap design is effective in breaking the midline vertical scar and preserving the gluteus maximus muscle.


The authors reported the case of a woman with a severe perineal defect secondary to a perianal cancer that required reconstruction from the posterior wall of the urinary bladder to the coccyx, and that laterally surpassed both ischial tuberosities. For this reconstructive work they used two V-Y advanced flaps taken from the gluteal region. On the basis of these flaps, they modified the final position in the advance of the lateral ends, crossing the tips of each flap over each other to provide a greater volume of tissue in the central area, with no signs of vascular injury. They concluded that the use of V-Y flaps, based on the perforating arteries of the gluteus maximus, allows the reconstruction of especially extensive defects in the perineal region. The technique is rapid and easy to perform and produces an acceptable clinical outcome with minimal morbidity.


Radiation therapy has a crucial role in the treatment of cancer; however, it may cause adverse effects to normal tissue such as radiation-induced ulcer and osteoradionecrosis. The few cases of conservative management that were reported had a limited value and unsatisfactory results. The most reliable method for treating sacral radiation ulcer and osteoradionecrosis is a wide excision of the affected tissue, followed by coverage with well-vascularized tissue. Myocutaneous free flaps and local gluteus maximus myocutaneous flaps have been used; however, there are many drawbacks, such as dissection of a recipient vessel in the previously irradiated area and donor site morbidity. During a 4-year period at their institute, the authors achieved favorable clinical results using gluteal artery perforator procedure for radiation-induced ulcers and osteoradionecrosis of the sacral area. The 10 patients who were treated with gluteal artery perforator flaps had chronic nonhealing radiation ulcers or bone exposure of the sacrum. Intraoperatively, massive debridement of bone and soft tissue was performed, while the well-vascularized skin with only a color change was preserved. The flap was designed to include two or more perforators using Doppler flowmetry, and the perforators were preserved with surrounding subcutaneous tissue during the flap elevation. The mean postoperative follow-up period was 25.7 months. There was one major complication (partial flap loss) and three minor complications (wound dehiscence). In the patient with partial flap loss from infection and a floating flap, the contralateral
superior gluteal artery perforator flap was used to treat the complication. Other complications were conservatively treated and healed well. Gluteal perforator flaps are a valuable alternative in treating sacral radiation ulcers and osteoradionecrosis. Sufficient excision of devitalized tissue is a crucial procedure to achieve optimal results.


To evaluate the role of the V-Y bilateral gluteus maximus myocutaneous flap in the reconstruction of large perineal defects after wide surgical resection for pelvic malignancies. Twelve consecutive patients (seven women and five men) 36 to 78 years of age (mean 59 years) with primary or recurrent pelvic malignancies (rectal, anal, and vulvar carcinoma) underwent either abdominoperineal rectum excision with partial sacrectomy or total pelvic exenteration. The perineal defect was reconstructed with a gluteus maximus myocutaneous flap. Intraoperative blood loss, operative time, hospital stay, postoperative complications, and long-term outcome were retrospectively assessed. One patient died postoperatively. All other patients had at least one early and/or late complication. After a mean follow-up of 31.2 months, seven patients were alive. No major functional impairment in daily activities was observed. Five patients had slight discomfort in either walking, sitting, or cycling.


Most women requiring tissue transfer to the chest for breast reconstruction or other reasons are candidates for IGAP or SGAP flaps. Because of a better donor site contour and scar, the authors now prefer to use the IGAP rather than the SGAP flap. Absolute contraindications specific to perforator flap breast reconstruction in their practice include a history of previous liposuction of the donor site or active smoking (within 1 month before surgery). IGAP and SGAP flaps are based on perforators from either the superior or inferior gluteal artery. These perforators are carefully dissected free from the surrounding gluteus maximus muscle, which is spread in the direction of the muscle fibers and safely preserved. The vascular pedicle is anastomosed to recipient vessels in the chest and the donor site closed primarily. IGAP and SGAP flaps allow the safe and reliable transfer of tissue from the buttock for breast reconstruction as an alternative to soft tissue transfer from an abdominal donor site or even as a first choice in selected patients.


The superior gluteal artery perforator (SGAP) flap is a useful technique for restoration of the breast after mastectomy. If appropriately planned, the soft tissue envelope supplied by the superior gluteal artery perforator vessels can be harvested with minimal donor site morbidity and often results in a highly aesthetic restoration of the breasts. Dissection of the flap is performed with complete preservation of gluteus maximus muscle function. The resulting vascular pedicle obtained via dissection through the muscle is longer than that of gluteal myocutaneous flaps and affords the surgeon the luxury of avoiding vein grafts in the anastomotic phase of surgery. Despite these advantages, the SGAP flap is not popular among reconstructive surgeons. Many practitioners are not familiar with the vascular anatomy of the gluteal area and may not be comfortable with dissection of the parent vessels, or lack the desire to practice microsurgery. The authors’ group previously reported the largest experience to date with this method of breast reconstruction and found the SGAP flap to be a reliable and safe method of autologous breast restoration in unilateral absence of the breast. Although the indications for performing single-stage gluteal tissue transplantation for bilateral breast restoration are uncommon,
they do occasionally arise in clinical practice. The authors carried out concurrent bilateral breast reconstruction using SGAP flaps on six patients, with acceptable overall morbidity. All flaps went on to survive and resulted in highly aesthetic restorations of the breast. Although a challenging undertaking, in-unison transfer of bilateral SGAP flaps serves as a useful option for a subset of patients desiring one-stage bilateral breast reconstruction.


The new design of the gluteus maximus perforator–based island flap for coverage of gluteal defects has the distinct advantage of being able to use customizable tissue components for coverage and at the same time sparing the source vessel. This adds a further option for use in reconstruction. After excisional debridement of the lesion, a perforator adjacent to the defect is selected. The tissue of the donor region is pinched to simulate closure. The change in shape of the recipient defect is noted and the dimensions of this new shape are measured. This will serve as the new dimensions of the donor tissue. The tissue components required to fill the defect are then analyzed and the flap is raised. It can be either muscle-sparing, muscle-splitting, or muscle-inclusive. A 1 to 2 cm diameter of soft tissue around the perforator is preserved. The flap is islanded and transposed, and the donor site is closed primarily, acting as a “locking barrier” to the flap. Tension-free closure of the recipient flap is then carried out. The authors reported on 75 patients who underwent closure of varying defects of the gluteal region using this technique. There were three minor complications; the rest of the patients healed well, with no recurrence at a mean follow-up of 15 months. The flap design for coverage of gluteal defects has a great impact on recurrence and complications. This design is novel and the flap is simple to elevate. This is an ideal flap in any high-risk patient in whom the risk of recurrence is high.


Various modifications of the gluteus maximus myocutaneous flap have been reported. Among them, the split gluteus maximus myocutaneous flap is easy to prepare and does not leave ambulatory insufficiency. However, the safety of extending the skin portion beyond the margin of the muscle has not yet been clarified. In the authors’ study, angiography was performed systemically on 11 fresh cadavers, and the distance the margin of the gluteus maximus muscle could be extended was noted. Based on these anatomic data, reconstruction after total skin resection of perianal and lower gluteal hidradenitis suppurativa was performed with an extended split superior gluteal maximus myocutaneous flap. Surgery was performed on three sides of two patients. From the results, the authors found that it is possible to extend the flap beyond the iliac crest several centimeters superiorly, and to the gluteal fold inferiorly, and several centimeters laterally. They designed the flap so that the extended area was situated in these areas. All flaps took well and did not show any congestion or necrosis. There were no recurrences at least 1 year after surgery. When reconstructing the lower part of the buttock, an extended split superior gluteus maximus myocutaneous flap is easy to raise and leaves aesthetically satisfactory results. Thus it may be the first choice for reconstruction of the lower buttock.


The large gluteus maximus muscle is sometimes used as a split muscle flap in reconstructive surgery. This article presented a reconstructive method based on three-dimensional arterial anatomy. The authors reported on six patients who underwent reconstruction with a split gluteus maximus myocutaneous flap. In all cases, the flaps took well without any evidence of necrosis.

Four patients diagnosed with sacral chordoma underwent reconstruction with the gluteus maximus flap using an approach based on available muscle remnants and their residual blood supply. The entire unilateral gluteus maximus muscle was turned over to fill the defect in two patients. The flap was based on one or two gluteal vessels, depending on vessel availability following tumor resection. When all four major pedicles had been ligated, bilateral advancement gluteal muscle flaps based on their distal blood supply were used (patient 3). A longitudinally split flap was used for secondary reconstruction of a partially obliterated defect (patient 4). Over a mean follow-up period of 8 months, there was no wound breakdown, and all patients were ambulant.


The gluteal perforator-based flap is designed according to the localization of sacral perforator vessels. These vessels penetrate the gluteus maximus muscle and reach the infrafascial and suprafascial planes, and the overlying skin forming a rich vascular plexus. The gluteal perforator-based flaps described in this paper are highly vascularized, have minimal donor site morbidity, do not require the sacrifice of the gluteus maximus muscle and rarely lead to postoperative complications. The authors concluded these easy-to-perform flaps might be considered as the first choice in the repair of gluteal pressure sores.


The authors retrospectively reviewed 11 consecutive septocutaneous gluteal artery perforator (sc-GAP) flaps performed for postmastectomy breast reconstruction in 9 patients between February and July of 2008. Patient demographics, risk factors, perforator characteristics, operative technique, operative time, and outcome were analyzed. Preoperative imaging was used for all patients. The patients ranged in age from 44 to 60 years (mean 52 years). Their body mass index ranged from 17.2 to 29.1 (mean 22.2). Of the 11 flaps, 5 sc-GAP flaps were immediate (45%) and 6 were delayed reconstruction (55%); 7 were unilateral (64%), and 4 were bilateral (36%). Mean operative time was 8.2 hours (range 6.5 to 11 hours). All patients stayed in the hospital for 5 days. Mean pedicle length was 7.9 cm (range 5 to 10 cm) and mean flap weight was 499 g (range 360 to 640 g). Vessel size ranged from 1.8 to 3 mm. Complications included one take-back, one axillary seroma, one donor site seroma, and one donor site hematoma. There were no flap losses.


Defects in the sacrococcygeal and ischial soft tissues can be treated with gluteus maximus and posterior thigh V-Y advancement flaps. However, late complications include recurrence and dehiscence of the suture line. Increasing the amount of soft tissue over the bony prominences and multilayered closure may have an advantage for long-term durability. The authors modified the V-Y advancement technique by deepithelializing the medial parts of the flap and burying them under the opposing edge of the wound or the flap. Sixteen patients with various defects of the sacrococcygeal and ischial soft tissues were operated on using this technique. All the flaps healed well, with no partial or complete loss of the flap. Three patients developed complications. The main advantage of the technique is the...
use of healthy tissues to obliterate the dead spaces under the edges of the wound or the opposing flap. In this way, not only the defect in the skin but the defect in the subcutaneous tissue, with its iceberg tip at the surface, is treated effectively. To have an additional layer of tissue between the bone and the superficial tissues provides an extra cushion of soft tissue and avoids putting the suture line directly over the bony prominences. The authors used this modification safely for both unilateral and bilateral flaps. It could also be used successfully in other parts of the body.


The free inferior gluteal flap is a major secondary choice of autologous tissue for breast reconstruction if the TRAM flap is not an option. Loss of posterior thigh and popliteal sensibility is a frequent sequela of harvesting the free inferior gluteal myocutaneous flap and the inferior gluteal artery perforator (IGAP) flap. The posterior femoral cutaneous nerve of the thigh lies directly on the deep surface of the gluteus maximus muscle, having a very close anatomic relationship with the inferior gluteal artery. The purpose of this study was to gain a better understanding of the anatomy of the posterior femoral cutaneous nerve (PFCN), its branches, and their relationship with the inferior gluteal artery (IGA). Eighteen fresh human pelvic halves were dissected for examination during harvesting of the inferior gluteal myocutaneous free flap, to determine whether a nerve-sparing approach was possible and how this information might affect an IGAP flap harvest. Seventeen of 18 pelvic halves had at least some of the PFCN branches intact after isolation of the IGA pedicle and flap elevation. Three of 18 of the pelvic halves had the entire PFCN and its branches intact after flap elevation. One of 18 pelvic halves required complete transection of the PFCN and its branches in order to isolate the IGA pedicle. In 94.5% of the pelvic halve dissections, it was possible to maintain at least a portion of the PFCN intact after isolation of the inferior gluteal artery pedicle while harvesting the free inferior gluteal myocutaneous flap. These findings support a nerve-sparing approach to inferior gluteal myocutaneous flap elevation to minimize the sequela of posterior thigh anesthesia. These data also emphasize the intimate relationship of the PFCN and the gluteal artery and the real possibility of injury to the PFCN during IGAP harvest.
**ANATOMIC LANDMARKS**

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>Posterior thigh from the gluteal crease to, but not including, the popliteal fossa. The flap is centered on the posterior thigh.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>$12 \times 30 \text{ cm}$</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Fasciocutaneous, type A.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Inferior gluteal artery.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td><em>Sensory:</em> Posterior femoral cutaneous nerve.</td>
</tr>
</tbody>
</table>
Section 7B

POSTERIOR TRUNK

Gluteal Thigh Flap

CLINICAL APPLICATIONS

Regional Use
- Trochanter
- Buttock
- Perineum

Specialized Use
- Vaginal reconstruction
Fig. 7B-1

Dominant pedicles: Inferior gluteal artery

ANATOMY OF THE GLUTEAL THIGH FLAP

Vascular anatomy of posterior thigh relative to gluteal thigh flap

Neural anatomy of gluteal thigh flap

Dominant pedicles: Inferior gluteal artery

A

B

Superior gluteal artery

Gluteus maximus muscle

Inferior gluteal artery

Descending branch of inferior gluteal artery

Posterior femoral cutaneous nerve

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1/31/2012   9:31:56 AM
ANATOMY

Landmarks Occupies the posterior portion of the thigh from the gluteal crease to, but not including, the popliteal fossa.

Composition Fasciocutaneous.

Size 12 × 30 cm. Primary closure is possible in flap widths 9 cm or less.

Arterial Anatomy

Dominant Pedicle Inferior gluteal artery

Regional Source Internal iliac artery.

Length 3 cm.

Diameter 2.5 mm.

Location The vessel runs with the posterior femoral cutaneous nerve, often within a sheath, in the majority of patients. Both structures are identified as they emerge from under the inferior border of the gluteus maximus muscle midway in the posterior thigh.

Venous Anatomy

Accompanying paired venae comitantes with the inferior gluteal artery.

Nerve Supply

Sensory Posterior femoral cutaneous nerve (S1 to S3) innervates the posterior thigh skin. It originates at the lower border of the piriformis muscle just medial to the sciatic nerve. It then runs inferiorly and deeply under the fascia lata, exiting from under the inferior border of the gluteus maximus muscle in the midline of the posterior thigh. At the level of the popliteal fossa the nerve penetrates the fascia and becomes subcutaneous over the posterior calf.
Vascular Anatomy of the Gluteal Thigh Flap

Dominant pedicle: Inferior gluteal artery (D₁)

n, Posterior femoral cutaneous nerve; arrows, cutaneous descending branch of inferior gluteal artery
FLAP HARVEST

Design and Markings
The skin paddle is designed over the midline of the posterior thigh. It is marked from the gluteal fold to the popliteal fossa. The inferior gluteal artery can supply the entire posterior thigh, and donor sites larger than 9 to 10 cm wide will need to be skin grafted. This is especially true as the flap approaches the popliteal fossa.

Patient Positioning
The patient is placed in the prone position for gluteal and trochanteric applications and the lithotomy position for perineal and vaginal applications.

Fig. 7B-3
Flap design
GUIDE TO FLAP DISSECTION

Once the flap is designed, it is dissected from distal to proximal. Medial, lateral, and inferior incisions can be made, and dissection is deepened down through the fascia. The fascia is then elevated from caudal to cephalad, with identification and inclusion of the posterior femoral cutaneous nerve and the inferior gluteal pedicle. Once the level of the gluteal fold and inferior border of the gluteus muscle is reached, some backcutting of the lateral incision can be performed to help rotation of the flap toward the perineum, or backcutting of the medial portion of the flap will allow more lateral rotation.

![Diagram of Gluteal Muscles and Nerves]

**Fig. 7B-4** The gluteal thigh flap is elevated to the gluteal crease and inferior border of the gluteus maximus muscle.
FLAP VARIANT

Extended Flap

When further extension of the flap is needed for reconstruction, dissection within the gluteus maximus muscle can be done. Care is taken to keep the inferior gluteal artery within the divided muscle. The lower third to half of the muscle can be elevated with the flap to give added length to the pedicle for rotation. Caution must be exercised during this maneuver to avoid injury to the inferior gluteal nerve, which is the motor nerve to the entire gluteus maximus muscle.

Fig. 7B-5
**ARC OF ROTATION**

The standard flap easily rotates to the trochanter and to beyond the midline in the perineum. A large dog-ear is created during these rotations, which can be dealt with later.

**FLAP TRANSFER**

The flap may be transposed either directly through a connection between the recipient and donor sites or through a subcutaneous tunnel. The subcutaneous tunnel is standard when flaps are used for vaginal reconstruction. Care must be taken to allow a large enough subcutaneous tunnel such that the pedicle of the flap is not compressed.

**FLAP INSET**

The tension of the flap must be carefully adjusted to avoid tension at the inset site; it is better to bear tension on the more proximal portion of the flap inset.

**DONOR SITE CLOSURE**

For more proximally based and smaller flaps with widths of 9 cm or less, primary closure is possible. For most applications where larger amounts of tissue are needed, it is harder to obtain primary closure, especially near the popliteal fossa, so skin grafting of the donor site is common.
CLINICAL APPLICATIONS
This 45-year-old woman with a history of squamous cell carcinoma of the labia underwent resection and postoperative irradiation. She presented with this deep, chronic, irradiated wound, with no vital structures exposed. Reconstruction was performed with a gluteal thigh flap.

Fig. 7B-7  A, Initial presentation of the wound without evidence of granulation or any wound healing. B, The gluteal thigh flap was elevated as an island flap, keeping all attachments to the underlying inferior gluteal vessels but incising the entire skin paddle to facilitate rotation. C, The inferior gluteal artery pedicle was identified and spared. D, The patient is seen 3 months postoperatively with a healed, sensate reconstruction. Note the skin grafting of the donor site required for closure. (Case supplied by MRZ.)
This 50-year-old woman had a history of rectal cancer and irradiation. She now required abdominoperineal resection for a recurrence. The perineal defect was reconstructed with a sensate gluteal thigh flap.

Fig. 7B-8  A, Design of the gluteal thigh flap. The inferior gluteal artery was identified with handheld Doppler, and the length of the flap was designed to cross the midline. B, The gluteal thigh flap is elevated to the inferior edge of the gluteus muscle. C, Identification of the inferior gluteal artery pedicle and the posterior femoral cutaneous nerve. No gluteal muscle was elevated. D, A large amount of tissue can be carried with this flap. The tissue is viable and easily reaches past the midline.
This 44-year-old woman was undergoing a total abdominal hysterectomy with removal of her vaginal vault for a carcinoma. She required total vaginal reconstruction. Bilateral gluteal thigh flaps were used to perform the reconstruction.

**Fig. 7B-8** E, The flap was inset to resurface the skin defect and to provide some fill of the dead space with well-vascularized tissue. Although two flaps were initially contemplated, one flap was adequate. Note that the proximal portion of the flap was not incised to maintain attachment and provide improved venous egress and lymphatic connections. The cone of rotation (dog-ear) is large but necessary initially for best blood supply to the flap. F, Oblique view shows that the flap was transposed via a direct incision, and a skin graft was required for closure. The patient healed uneventfully and did not require secondary revisions. (Case supplied by MRZ.)

**Fig. 7B-9** A, At laparotomy: there was no vaginal vault and there were no external perineal incisions. Two gluteal thigh flaps were designed for sensate total vaginal vault reconstruction. B, The flaps were inset after passing them through a subcutaneous tunnel and attaching them to each other to reform a vaginal vault. The flap on the left can be seen. The donor sites were closed primarily, and no revisions were required. (Case supplied by MRZ.)
This 25-year-old man had invasive squamous cell carcinoma of the perineum and a history of Crohn’s disease. A gluteal thigh flap was planned.

**Fig. 7B-10** A, The patient's condition was complicated by recurrent fistulas. B, Bilateral gluteal thigh fasciocutaneous flaps were designed to provide coverage before postoperative radiation therapy was initiated. C, The neurovascular pedicle was identified at the inferior border of the gluteus maximus muscle. D and E, The bilateral flaps were tunneled beneath intact skin bridges that separated the wounds from the bases of the flaps. F, Delayed flap compression led to flap necrosis from the pressure of the overlying skin bridge at the base of the pedicle. Complete release of the intervening skin bridge might have prevented venous congestion and ultimate partial flap loss. (Case courtesy Jeffrey D. Friedman, MD.)
This 72-year-old woman underwent wide local excision of a recurrent squamous cell carcinoma of the vulva and vagina. This resulted in a large soft tissue defect of the medial buttock, vulva, and posterior vagina. She underwent radiation therapy to the perineum.

**Fig. 7B-11**  
A, The patient’s soft tissue defect is seen. B and C, Bilateral gluteal thigh fasciocutaneous flaps were designed and elevated; the ablative procedure was performed through a perineal approach. D, Flap inset allowed primary closure. E, Excellent healing is evident at 6 months postoperatively. (Case courtesy Jeffrey D. Friedman, MD.)
This 64-year-old man presented with a 2-year history of a chronic irradiated sacral-perineal wound.

**Fig. 7B-12**  
A, The defect is shown; the patient had undergone radiation therapy and posterior exenteration for advanced carcinoma of the prostate.  
B, The patient had both urinary and fecal diversion.  
C and D, Gluteal thigh fasciocutaneous flaps were designed and elevated to provide both soft tissue fill for the large pelvic defect and closure of the skin defect.  
E and F, Early and late results demonstrate uneventful healing. (Case courtesy Jeffrey D. Friedman, MD.)
This 52-year-old man had a recurrent perianal fistula after localized radiation therapy for carcinoma of the prostate.

Fig. 7B-13  A, The defect is shown. B, Multiple local procedures had failed to correct the recurrence of the fistula. C and D, A unilateral gluteal thigh fasciocutaneous flap was designed and elevated to provide soft tissue separation of the rectum from the distal urinary tract and external skin replacement of the perianal skin. E, Closure of the wound. (Case courtesy Jeffrey D. Friedman, MD.)
This young woman had a history of Crohn’s disease; she developed advanced squamous cell carcinoma of the perineum.

Fig. 7B-14  A, She underwent abdominoperineal resection, a posterior vaginectomy, and wide soft tissue resection of the perineum. B and C, A single vertical rectus abdominis myocutaneous flap was found to be insufficient to provide vaginal reconstruction and soft tissue reconstruction of the perineal defect.
Fig. 7B-14  D-F, Bilateral gluteal thigh fasciocutaneous flaps were used to close the remainder of the perineal wound. G, Long-term results were favorable and allowed functional vaginal reconstruction and stable wound closure despite a postoperative course of radiation therapy. (Case courtesy Jeffrey D. Friedman, MD.)
**Pearls and Pitfalls**

- The large cone of rotation or dog-ear that is common with these flaps should be dealt with secondarily. Although the temptation is to remove these immediately, such removal will make the flaps ischemic and will cause the reconstruction to fail. A minimum delay of 4 to 6 months should be planned before any revisions are done.

- The patient should be warned about paresthesia in the posterior thigh and calf from division of the posterior femoral cutaneous nerve.

- Although visualization of the inferior gluteal pedicle is useful, the wide based design of the flap allows elevation and rotation of the flap without specific identification.

- Care should be taken in splitting the gluteal muscle, especially in an ambulatory patient. Although patients can tolerate losing up to half of the gluteus muscle and still have a normal gait, injury to the inferior gluteal nerve, which innervates the entire gluteus muscle, could be devastating.

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**EXPERT COMMENTARY**

Jeffrey D. Friedman

**Indications**

The gluteal thigh flap (also called the posterior thigh flap or inferior gluteal thigh flap) remains a useful tool for the reconstruction of various defects in the vaginoperineal region. In most cases, this flap provides relatively thin, pliable, soft tissue that can be used for a variety of reconstructive purposes in this area. Given the location of the vascular pedicle proximally at the level of the gluteal crease, there is a relatively generous arc of rotation for the flap in terms of reach within the pelvis. The gluteal thigh flap can thus be used to provide soft tissue coverage of open defects in and around the pelvis and can facilitate functional reconstruction for both congenital and acquired deformities.

The various uses for the gluteal thigh flap are somewhat different in males and females. Reconstruction in men tends to involve either large soft tissue defects of the perineum resulting from oncologic excision of colorectal cancers, or treatment for fistulous disease after radical prostatectomy. Female patients present many more challenges, because deformities in women typically have a functional component that adds a level of complexity to their treatment. The gluteal thigh flap can be used not only for soft tissue reconstruction of large pelvic and vulvar defects, but also to provide functional restoration of partial or total defects of the vaginal vault.

**Advantages and Limitations**

As described in this chapter, the flap is relatively simple to design and elevate. However, the distal portion of the flap, which has been described to extend to the proximal flexion crease of the knee, may be somewhat unreliable. Generally, a large amount of skin and underlying soft tissue can be raised with this flap. Obviously, this depends on the extent of redundant tissue in the patient’s posterior thigh. In most cases, there is an inverse relationship between the amount of available skin and the volume of the underlying soft tissue. In thin patients,
typically there is considerable excess of skin in the posterior thigh; however, there is a limited volume of available soft tissue. In large or obese patients, there are often moderate degrees of available subcutaneous tissue, although the amount of available skin in these patients is quite restricted.

Therefore, when planning a gluteal thigh flap, the surgeon must assess these factors preoperatively in light of the patient’s reconstructive needs. For large soft tissue defects of the perineum and for most cases of total vaginal reconstruction, one flap may be insufficient, and bilateral flaps will be required. Depending on the size of these defects and the relative laxity of the underlying soft tissues in the posterior region of the thigh, variable amounts of soft tissue can be harvested without the need for a skin graft at the donor site. When primary closure is not an option, the donor site can often leave a moderate cosmetic deformity, and this must be weighed against the patient’s reconstructive needs and other possible flap choices.

**Anatomic Considerations**

In large part, the consistent neurovascular anatomy of the gluteal thigh flap means that it is relatively straightforward to elevate and transfer the flap to the pelvis. The close proximity of the posterior femoral cutaneous nerve to the inferior gluteal pedicle enables one to raise the gluteal thigh flap as a sensate fasciocutaneous flap. Although the advantages of this are readily apparent, placement of a sensate flap in the region of the perineum or along one of the vaginal walls may, in some cases, be problematic. The sensation of stimulation along the posterior thigh during intercourse or when pressure is applied to the perineum can be quite bothersome for many patients. However, because of the proximity of the nerve to the vascular pedicle, dividing the nerve at the time of initial transfer may place the vascular pedicle at risk. Therefore I think it is safer to divide the nerve as a secondary procedure if this sensation is disturbing to the patient. At such time, vascular ingrowth has generally developed from the recipient bed, so compromise of the entire flap is no longer a concern.

**Personal Experience and Insights**

The gluteal thigh flap is a valuable tool in the reconstruction of vaginoperineal deformities—although in most cases, this flap is not the first choice when addressing these complex reconstructions. In my experience, most perineal defects are created at the time of extirpative pelvic surgery. In such cases, a laparotomy is typically performed, which provides easy access to the pelvis from the anterior abdominal region. Thus variations of the rectus abdominis myocutaneous flap can be easily transferred to the pelvis to provide soft tissue and skin to the region. Exceptions to this include patients who will undergo both fecal and urinary diversion. In this situation, two stomas are required, thus making the use of the rectus muscles problematic for abdominal wound healing. Use of the gluteal thigh flap can avoid compromise of abdominal wall integrity.

The more common indications for the gluteal thigh flap are perineal reconstructions that do not require laparotomy for access to the pelvis or in cases where flaps from the abdominal wall have previously been used. While gracilis myocutaneous flaps have frequently been used under these circumstances, I have found the gracilis flap to be relatively unreliable because of the bulkiness of the skin paddle or the inadequate reach and poor vascularity of the distal skin island.
Recommendations

Planning

Planning for the gluteal thigh flap is critical. Patients must be marked in the upright position before surgery, since the anatomic landmarks of the posterior thigh become quite distorted when the patient is in the dorsal lithotomy position. If findings are normal on vascular examination, use of the Doppler to identify the pedicle is generally unnecessary. However, the Doppler probe may be useful intraoperatively in identifying the proximal pedicle.

Technique

Dissection of the flap is relatively straightforward and begins distally, extending in a proximal direction. The fascia of the posterior compartment must be included with the flap and is best secured to the skin margins with sutures. As one nears the proximal pedicle, it is best to extend the incision along the lateral side of the skin paddle and move medially toward the pedicle once the inferior gluteal pedicle has been clearly identified. Creation of an island pedicle flap is generally discouraged, because it is fraught with the potential for early or late vascular compromise.

The critical portion of this flap procedure lies in the transfer of the gluteal thigh flap into the pelvic region. This generally requires creation of a tunnel between the defect and the upper thigh. If the skin bridge is to be left intact, it is imperative that the superficial fascia of the intervening skin bridge be released to prevent excessive pressure on the flap in situ. Should this be found to be constricting, division of the skin bridge can avoid late necrosis of the distal skin paddle (see Fig. 7B-10, F).

Postoperative Care

Postoperatively, pressure on the vascular pedicle must be avoided. Patients are instructed not to sit, but to lie supine, prone, or in the lateral position or to stand during the first 2 postoperative weeks. Sitting is expressly prohibited, because this causes too much pressure on the flap and risks early flap loss. A gradual sitting program is recommended after this 2-week period.

Take-Away Messages

The gluteal thigh flap is a reliable transfer flap for perineal reconstruction in selected patients. This is particularly true in primary cases in which patients will have both urinary and fecal diversion or when an isolated perineal approach is performed. I have also found the gluteal thigh flap to be useful when previous abdominal-based flaps have either been used or are no longer available for transfer. These cases are generally quite challenging because of scarring and radiation effects. However, when the gluteal thigh flap is elevated and transferred as described, these complex deformities can be reliably treated with few complications and excellent clinical outcomes.
Bibliography With Key Annotations


Animal research has added a great deal of understanding to flap hemodynamics. The rat is the most commonly used animal in flap research, and various flap models have been devised. In the current study the authors developed a single-perforator–based flap model in rats. In 30 rats, anatomic dissection and flap elevation based on a single myocutaneous perforator artery arising from the biceps femoris muscle were performed. The vascular basis of this new flap was cleared by anatomic dissection of the posterior thigh in six rats. The survival pattern of the proposed flap was investigated in three groups of rats. Each group consisted of eight rats and had different flap dimensions. In the first group the flap was located in the posterior thigh and was 3 by 2 cm. All flaps survived in this group at the end of the first week. In the second group the same flap was extended to the gluteal region and was 3 by 4 cm. Again, all flaps survived. In the last group an oversized flap (3 by 12 cm) was planned from the posterior thigh to the scapular region based on the same perforator artery. In this group only 61% of the flaps survived at the end of the first week. Microangiography was performed in each group and the vascular architecture of the pedicle (perforator artery) was seen. This new posterior thigh perforator-based flap model is simple and reliable with a constant survival pattern. Thus it could be used in studies investigating the physiologic and pathophysiologic changes of perforator-based flaps.


In this study the authors reviewed their experience with the posterior thigh flap as an alternative to the more commonly performed transfers for difficult wounds of the perineum and pelvic structures. A total of 27 posterior thigh flaps were used in 19 patients for complex perineal wound closure. Successful transfer of the posterior thigh flap was noted in 26 of 27 flaps (11 unilateral and 8 bilateral), with only one flap failure (3.7%). Primary wound healing was ultimately achieved in all patients; however, early wound-healing complications were common (53%). Secondary procedures were necessary in seven patients (37%), with only one patient requiring a secondary flap procedure. The authors found the posterior thigh flap to be a useful and reliable flap for coverage of complex perineal wounds. This was particularly true for patients in whom a laparotomy was best avoided and those who had both a urinary and a fecal diversion.


A compound thigh flap, which includes the central portion of posterior thigh skin and deep fascia and the inferior half of the glutus maximus muscle, was used to close a large cavity in the perineum and posterior pelvis. Features of this flap design include (1) a pedicle based on the inferior gluteal artery with a direct cutaneous artery and posterior thigh flap, (2) a point of flap rotation superior to the ischial tuberosity, (3) a sensory flap with a posterior femoral cutaneous nerve, (4) the potential for direct donor site closure, and (5) the superior half of the glutus maximus muscle remaining intact for function preservation.


Evaluation of the vascular anatomy of the inferior gluteal artery confirms its blood supply through both the overlying gluteal skin and the posterior thigh via a direct cutaneous artery deep to the thigh fascia. This direct cutaneous pedicle is located in the midposterior thigh adjacent to the posterior cutaneous nerve. The flap design is centered on a vertical line located midway between the greater trochanter and the ischial tuberosity with the distal flap border located 8 cm superior to the popliteal fossa. With the flap point of rotation 5 cm above the ischial tuberosity, the flap will reach pelvic, perineal, and lateral
trunk defects. The authors reported successful closure of 18 of 21 complex wounds of the perineum and buttock regions. The flap dimensions ranged from 12 to 35 cm in length and 6 to 15 cm in width. In the three patients in whom distal flap loss was observed, the flap complications were from hematoma, pressure on the flap, and flap dehiscence, respectively. The authors recommended this flap for closure of midline deep anal-perineal wounds and ischial-sacral pressure sores and posterior pelvic defects.


The authors provided five examples of patients with complex lower midline truncal wounds successfully reconstructed with a gluteal thigh flap. The donor sites of the flaps were closed directly. In a review of 40 patients under 65 years of age, the gluteal flaps were successfully used to treat 50 wounds.


Pectus excavatum is typically a cosmetic congenital chest wall deformity. In most cases, it does not affect heart and lung function; therefore, because of their high rate of complications, extensive procedures need not be performed. Various alternative techniques (such as reconstruction with a silicone prosthesis or the TRAM flap) were introduced in asymptomatic pectus excavatum. All of these methods have their advantages but also limitations. Thus the authors used a free fasciocutaneous infragluteal flap for reconstruction of asymptomatic pectus excavatum in selected patients. Between 2001 and 2007, six patients with asymptomatic pectus excavatum underwent correction with the free fasciocutaneous infragluteal flap. This flap is based on a constant end artery of the inferior gluteal artery. After raising the flap and wound closure in the buttock region, the flap was adjusted to the defect using a small skin incision in the inframammary fold, and the vessels were anastomosed. There were no flap losses and no major complications. One patient suffered from a sensory change at the posterior thigh in the early postoperative period that resolved completely within 2 weeks. In four cases, flap shaping or liposuction was performed to improve the aesthetic result. In the authors' final evaluation, all patients were very satisfied with the result and would undergo the procedure again. The authors demonstrated for the first time the reconstruction of asymptomatic pectus excavatum with the free fasciocutaneous infragluteal flap. They concluded that in selected patients, this flap offers an excellent alternative to established techniques for this problem.


A new axial pattern flap based on the terminal branches of the medial circumflex femoral artery was described for coverage of ischial pressure sore. Based on the terminal branches of the transverse branch of medial circumflex femoral artery, which exit through the gap between the quadratus femoris muscle above and the upper border of adductor magnus muscle below, this fasciocutaneous flap is much smaller than the posterior thigh flap but extremely useful to cover ischial pressure sores. The skin redundancy below the gluteal fold allows a primary closure of the donor defect. It can also be used in combination with the biceps femoris muscle flap.


The angiosomes of the body were defined in 1987. The recent popularity of skin perforator and muscle flaps designed in the thigh, together with significant major vessel anomaly and disease, has necessitated a more detailed reevaluation of the blood supply to this region. Eighteen new studies, combined with a review of 36 of the authors' archival studies of the buttock and the thigh, have been conducted in fresh human cadavers using arterial perfusion with a radiographic lead oxide mixture. The angiosome territories of the lumbar, deep circumflex iliac, sacral, gluteal, common femoral, superficial femoral, lateral femoral circumflex, medial femoral circumflex, profunda, descending genicular, and popliteal source vessels that contribute to the thigh and buttock were defined between the skin
and the bone. The dominant cutaneous supply of perforators of 0.5 mm or greater emerged from the deep fascia predominantly in longitudinal rows from the intermuscular septa or from intramuscular septa, especially from the buttock muscles. Each muscle was supplied from two or more angiosomes, thereby constituting important bypass shunts for potential major vessel injury or disease, by means of their intramuscular anastomoses. These results may help surgeons in the design of skin perforator and refined muscle, myocutaneous, and composite flaps in the thigh and the buttock. The study also provides a better understanding of vessel anastomoses in the region.


The authors proposed classifying patients with pelvic wound defects into three functional categories: (1) spinal cord injury with no sensation and no motor function, (2) spinal cord injury with partial sensory and motor function, and (3) miscellaneous injury (trauma and tumor resections). The posterior thigh flap represents the technique of choice for both ischial and sacral wounds. Their experience with closure of pelvic sores in 31 patients included 27 gluteal thigh flaps—19 island flaps and 8 combined gluteal thigh flaps. There were 4 island flap complications involving partial flap loss (21%) and 1 complete flap loss (5.3%). In the gluteal thigh or combined flap, there was 1 flap complication (13%) that resulted in partial flap loss. In category 1 patients, the authors advocated the use of the gluteal thigh flap for shallow defects without osteomyelitis. A standard muscle flap is preferred for more complex defects involving bone infection. In category 2 and 3 patients, the gluteal thigh flap is preferred, since functional muscles are not required in the flap design.


The objective of this study was to assess the reconstructive options after radical, extensive vulvectomy, relate them to tumor characteristics, and select a choice of flaps able to correct every remaining defect. This study was a retrospective review of a 4-year experience with 31 flaps in 20 consecutive vulvar reconstructions. Three of the 31 flaps presented nonsignificant delayed healing at their tips, and three other flaps developed a major breakdown related to an infection or an error in flap planning. According to the authors, the size of the defect is the main issue that must be taken into consideration during the establishment of reconstructive needs. Closure of vulvar defects is preferably performed using fasciocutaneous flaps, which are very reliable flaps and can be raised with different techniques to meet different needs. A flap is then chosen with the fewest potential complications. An algorithm has been thus established. Small to medium-sized defects are closed with island V-Y flaps, island gluteal fold flaps, or pedicled pudendal thigh flaps. Among them, the island V-Y flap is the workhorse flap for vulvar reconstruction because of its versatility, reliability, and technical simplicity compared with its very low complication rate. If the vulvar defect is large and/or reaches the vulva-crural fold, V-Y flaps are also preferred to close these large and posteriorly extended excisions. If the vulvar defect is very large, extending both anteriorly and posteriorly, the use of a distally based, vertically oriented rectus abdominis muscle flap is recommended. Using this algorithm, immediate vulvar reconstruction with pedicled local or regional flaps can be performed easily and reliably.


When selecting flaps for coverage of pressure ulcers of the sacrum and perineal region in paraplegic patients, surgeons should consider long-term recurrence rates. Therefore the authors developed an infragluteal perforator flap to avoid “burning bridges” for future reconstruction. Infragluteal perforator flaps were dissected in five fresh human cadavers to define the anatomy of the cutaneous branches of the descending branch of the inferior gluteal artery and cluneal nerves and define anatomic landmarks for clinical application. In a series of 13 paraplegic patients, the authors used perforator-based flaps (additional skin bridge) to cover four perineal ulcers and one sacral ulcer and perforator flaps to cover six perineal and two sacral ulcers. Donor sites were closed by direct approximation. Twelve of 13
flaps healed uneventfully. In all cadaver and clinical dissections, one or two cutaneous branches of the descending branch of the inferior gluteal artery and one or two cluneal nerves were found at the lower border of the gluteus maximus muscle supplying the infragluteal perforator flap. These direct cutaneous branches allowed dissection of inferior gluteal perforator flaps with improved flap mobility compared with the perforator-based flaps. The descending branch of the inferior gluteal artery could always be spared for future flaps. The infragluteal perforator flap is a versatile and reliable flap for coverage of ischial and sacral pressure sores. It can be designed as a perforator-based or perforator flap and could provide a sensate flap in ambulatory patients. Donor site morbidity is minimal, and options for future flaps of the gluteal and posterior thigh region are preserved.


Two patients presented with squamous cell carcinoma in areas of chronic perirectal fistula and chronic ischial pressure sores, respectively, that required surgical resection. Each patient had previously undergone fecal diversion and colostomy. Mohs micrographic technique was used to determine tumor margins during the ablative procedure. Subsequent defects were successfully reconstructed with a gluteal thigh flap in both patients.


Reconstructive surgery for ischial pressure sore defects presents a challenge because of high rates of recurrence. The aim of this study was to describe the use of inferior gluteal artery (IGA) and posterior thigh perforators in management of ischial pressure sores with limited donor sites. Between September 2005 and 2009, the authors operated on 11 patients (9 men, 2 women) with ischial sores with IGAP and posterior thigh perforator flaps. The data on patients included age, sex, cause of paraplegia, flap size, perforator of flap, previous surgeries, recurrences, complications, and postoperative follow-up. Nine IGAP and 5 posterior thigh perforator flaps were used. Six patients presented with recurrent lesions; 5 patients had previously undergone surgery for sacral and contralateral ischial pressure sores. In 2 patients IGAP and posterior thigh perforator flaps were used in combination. Patients were followed for an average of 34.3 months. In two recurrent cases, readvancement of the IGAP flap and gluteus maximus myocutaneous flap procedures were the treatment of choice. Treatment of patients with recurrent lesions or multiple pressure sores is challenging because flap donor sites are limited.


Surgeons performing flap surgery in the distal part of the gluteal region have had to contend with a lack of detailed descriptions of the inferior gluteal artery and the posterior femoral cutaneous nerve. The existing papers are mainly clinical studies, based on low numbers of observations. The authors’ study included 118 cadaveric gluteal regions. The descending branch was present in 91% and gave rise to a cutaneous branch. When the descending branch was absent, this cutaneous branch came from the medial or lateral femoral circumflex artery or as a perforator of the deep artery of the thigh. The posterior femoral cutaneous nerve was found in a common sheath of connective tissue with the descending branch of the inferior gluteal artery in 72% of cases. Nerve loops around the vessel were present in 29%. The results show that a cutaneous or fasciocutaneous flap, either local or free, in this region can be reliably lifted on a cutaneous branch of the descending branch of the inferior gluteal artery...
Posterior Trunk

7B: Gluteal Thigh Flap

artery without loss of sensitivity. However, the close relationship of the artery and nerve limits the arc of rotation in the case of a local flap.


The free inferior gluteal flap is a major secondary choice of autologous tissue for breast reconstruction if the TRAM flap is not an option. Loss of posterior thigh and popliteal sensibility is a frequent sequela of harvesting the free inferior gluteal myocutaneous flap and the inferior gluteal artery perforator (IGAP) flap. The posterior femoral cutaneous nerve of the thigh lies directly on the deep surface of the gluteus maximus muscle, having a very close anatomic relationship with the inferior gluteal artery. The purpose of this study was to gain a better understanding of the anatomy of the posterior femoral cutaneous nerve (PFCN), its branches, and their relationship with the inferior gluteal artery (IGA). Eighteen fresh human pelvic halves were dissected for examination during harvesting of the inferior gluteal myocutaneous free flap, to determine if a nerve-sparing approach was possible and how this information might impact on IGAP flap harvest. Seventeen of 18 pelvic halves had at least some of the PFCN branches intact after isolation of the IGA pedicle and flap elevation. Three of 18 of the pelvic halves had the entire PFCN and its branches intact after flap elevation. One of 18 pelvic halves required complete transaction of the PFCN and its branches in order to isolate the IGA pedicle. In 94.5% of the pelvic half dissections, it was possible to maintain at least a portion of the PFCN intact after isolation of the inferior gluteal artery pedicle while harvesting the free inferior gluteal myocutaneous flap. These findings support a nerve-sparing approach to inferior gluteal myocutaneous flap elevation to minimize the sequelae of posterior thigh anesthesia. These data also emphasize the intimate relationship of the PFCN and the gluteal artery and the real possibility of injury to the PFCN during IGAP harvest.


To determine the vascular anatomy and clinical applications of superiorly and inferiorly based posterior thigh fasciocutaneous flaps, the authors conducted a study of 10 consecutive patients who underwent resection of malignant tumors, five malignant fibrous histiocytomas (MFH), two synovial sarcomas, one skin squamous cell cancer, one malignant hamartoma, and one fibrosarcoma. The average age of the patients was 49 years (range 25 to 71 years), with 6 men and 4 women. Superior defects, including two in the sacrococcygeal region and one lesion over the femoral greater trochanter, were closed with superior posterior femoral fasciocutaneous flaps (SPFFCF). Seven lesions, three in the popliteal fossae and two in the lateral and two medial knee regions, were closed with inferior posterior femoral fasciocutaneous flaps (IPFFCF). The average flap size was 148 cm² (range 90 to 300 cm²). The average follow-up period was 23 months (range 3 to 50 months). Patients were assessed by examination of the vascular anatomy, the operation technique and the treatment outcome. In particular the fasciocutaneous network and the descending branch of the inferior gluteal artery of the nutrient flap were analyzed.

There were no total skin flap failures and no significant complications. Tumor recurred locally in two patients and lung metastases occurred in another two. Five patients returned to their original jobs and daily activity without limitation, but two experienced decreased knee flexion of 30 degrees. The larger SPFFCF is based on the fasciocutaneous branch of the inferior gluteal artery accompanied by the posterior gluteal cutaneous nerve. The larger SPFFCF, which includes the fascia lata femoris and the fasciocutaneous branch with the posterior femoral cutaneous nerve, does not include the first cutaneous branch of the fasciocutaneous branch artery. Hence large defects of the sacrococcygeal region and the femoral greater trochanter can be reconstructed using an SPFFCF. Defects around the knee can be reconstructed with an IPFFCF, which is based on the ascending branch of the fasciocutaneous branch of the third perforating artery.
ANATOMIC LANDMARKS

**Landmarks**
This large fasciocutaneous territory extends from the midline to the posterior axillary line and from the scapular spine to the midback.

**Size**
12 × 25 cm with primary closure; larger size up to 20 × 35 cm with skin grafting of the donor site. Size can be further increased by tissue expansion.

**Composition**
Fascial or fasciocutaneous.

**Dominant Pedicle**
Circumflex scapular artery.

**Nerve Supply**
Cervical plexus, dorsal nerve roots, circumflex nerves.
Section 7C

POSTERIOR TRUNK

Scapular/Parascapular Flap

CLINICAL APPLICATIONS

Regional Use
- Axilla
- Shoulder
- Back
- Upper extremity

Distant Use
- Cutaneous
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Facial augmentation
ANATOMY OF THE SCAPULAR/PARASCAPULAR FLAP

**Fig. 7C-1**  
A. The blood supply of the scapular system. B. The circumflex scapular artery is seen exiting the triangular space. The orientations of the four major dorsal thoracic fascia flaps are outlined, each based on its discrete and usually consistent tributary: anterior (inframammary extended circumflex scapular); ascending (ascending scapular); descending (parascapular); horizontal (scapular). C. The subscapular artery arises from the third portion of the axillary artery on its inferior margin. It divides into the circumflex scapular artery and the thoracodorsal artery.  
**Dominant pedicle:** Circumflex scapular artery
ANATOMY

Landmarks The triangular space must be identified to safely design the scapular flap. The space is defined by the teres major inferiorly, the teres minor superiorly, and the long head of the triceps laterally. It is through this space that the circumflex scapular vessels emerge; the exact point can be found by palpation and can be confirmed by Doppler ultrasonography. The approximate location of the triangular space can also be palpated on the lateral scapular border, where it lies two fifths the distance from the scapular spine to the scapular tip. The lateral extension of the flap can be to the midaxillary line, and medially, the flap can be designed to the vertebral column. Superiorly, the flap can be harvested from just above the scapular spine, and inferiorly, at least to the angle of the scapula and as far as the midback.

Composition The scapular flap can be harvested as a cutaneous flap, an adipofascial flap, an osseous flap, or any combination of the above.

Size 12 × 25 cm with primary closure; larger size up to 20 × 35 cm with skin grafting of the donor site or tissue expansion. Although flap design is limited by the ability to close the donor site, a flap of 10 to 12 cm usually can be closed primarily and the length can be 25 cm or more, as long as the design remains within the confines of the landmarks described above. Larger skin paddles can be harvested but would require skin grafting to the donor site, tissue expansion, or a delay procedure. The length of bone that can be harvested depends on the patient’s size and can be harvested from the lateral or medial border of the scapula, with bony length as large as 14 cm.

Arterial Anatomy

Dominant Pedicle Circumflex scapular artery

Regional Source Axillary artery.

Length 4 cm.

Diameter 2.5 to 4 mm.

Location The triangular space is defined by the teres major inferiorly, the teres minor superiorly, and the long head of the triceps laterally. It is through this space that the circumflex scapular vessels emerge. The subscapular artery arises from the third portion of the axillary artery; after 2 to 3 cm, it divides into a circumflex scapular artery and a thoracodorsal artery. At this point the circumflex scapular artery is 4 mm in external diameter. The circumflex scapular artery then runs 3 to 4 cm as it passes through the triangular space; once in the space, it sends branches to the subscapularis muscle as well as to the scapula, providing the vascularization for the lateral bone flap. The artery divides generally into a descending branch (parascapular branch), a transverse branch (scapular branch), and ascending branches. Flaps based on the descending branch are referred to as parascapular flaps, whereas flaps based on the more transverse or superior vessels have been called scapular flaps, although the flap composition and source vessels are the same. The transverse vessels supply the medial osseous segment, which is largely through fasciocutaneous connections and not direct musculoperiosteal branches, as is seen with the lateral osseous flap.
Venous Anatomy

Two venae comitantes accompany the artery; one vein is usually larger, measuring approximately 4.5 mm in diameter at the level of the circumflex scapular vein. The smaller vein is frequently 1.5 to 2.5 mm in diameter.

Nerve Supply

Sensory

Innervation of this area is from the cervical plexus, the dorsal nerve roots, and the circumflex nerves. There is no nerve that can be harvested with the flap to make it sensate.

**Vascular Anatomy of the Scapular/Parascapular Flap**

![Deep surface of flap](image1)
![Radiographic view](image2)

![Cutaneous surface of flap with lateral segment of scapula (vascularized bone)](image3)
![Radiographic view](image4)

**Fig. 7C-2**

**Dominant pedicle:** Circumflex scapular artery (D)

p, Periosteal branch to scapula; s, subscapular artery; t, thoracodorsal artery
FLAP HARVEST

Design and Markings
The patient is marked in a standing or sitting position; the marks are then confirmed once the patient is positioned on the operating table. The design begins with palpation of the triangular space. Next, based on tissue needs, the relaxed skin tension lines of this area of the back are determined, and the skin paddle is designed accordingly. Any skin paddle design that incorporates the circumflex scapular vessels as they emerge from the triangular space will be well vascularized. It is advisable to place the axis of the flap along either the descending or transverse branches; this can be confirmed by surface Doppler ultrasonography. If the width of the skin paddle design is kept at 10 cm or less, primary closure can be done. For an osteocutaneous flap, the cutaneous segment is planned separately, as noted previously. Based on the length of the desired flap and the thickness of bone stock, either a medial or a lateral osseous segment can be harvested the width of the flap, and no further skin incisions are necessary to facilitate this.

Fig. 7C-3  A, Outline of the scapular and parascapular flaps based on the scapular cutaneous artery and parascapular cutaneous artery, respectively. These are both terminal branches of the descending branch of the circumflex scapular artery, seen exiting through the triangular space. B, The triangular space can usually be identified by palpation. An approximate location can be marked at the lateral border of the scapula, two fifths the distance inferiorly on a line connecting the midportion of the spine of the scapula to its inferior angle.
Patient Positioning

Positioning for harvest of the scapular flap will depend on its clinical application. When possible, lateral decubitus positioning is preferred, especially when the recipient site can also be prepared in this position, either as a pedicle or free flap. For a free flap, this allows a two-team approach.

Many head and neck applications require repositioning of the patient; therefore harvesting with the patient in either the lateral decubitus or prone position depends on the surgeon's preference. For rotational flaps of the axilla or shoulder, a lateral decubitus position with the arm prepared into the field is preferred.

A

Lateral decubitus position

B

Prone position

Fig. 7C-4
GUIDE TO FLAP DISSECTION

Once the flap has been designed, based on identification of the triangular space and the amount of tissue required at the recipient site, one of two approaches can be used to dissect the skin paddle. In the first approach the superior flap border and lateral flap border are incised, and dissection proceeds directly to the triangular space. Fascia from the deltoid and teres muscles can be taken to allow a safe passage into the triangular space, but this fascia must be opened to identify the sizable circumflex scapular vessels. Then the remainder of the incisions in the flap can be made, and the flap can rapidly be raised from medial to lateral and from inferior to superior surrounding the triangular space.

In the second approach the pedicle is not identified immediately; rather, the medialmost and inferiormost portions of the flap are elevated and quickly dissected toward the triangular space. A subfascial plane is maintained as the lateral edge of the scapula is approached. Again, the triangular space is surrounded by including the fascia from the teres major and teres minor muscles, and once dissection is carried down into the triangular space, this fascia is entered; the areolar tissues encountered contain the circumflex scapular vessels. At this point, small muscle branches to the teres minor and teres major are divided, and deep retractors can be placed, opening the triangular space and facilitating dissection of the vessel toward the subscapular system. Branching of the circumflex scapular vessels can be seen within the space, and the descending branch is noted to pass around the lateral border of the scapula, with direct blood vessels to the periosteum. If a skin or adipofascial flap only is desired, the vessel to the bone is divided and the pedicle is lengthened by further dissection. The pedicle length is approximately 4 cm at this point; this can be further lengthened by dividing the thoracodorsal vessels and extending the dissection into the subscapular system.
FLAP VARIANTS
- Adipofascial flap
- Osteocutaneous flap
- Bone-only

Adipofascial Flap
When soft tissue lining or soft tissue fill is the reconstructive goal, as in a Romberg’s hemifacial atrophy case, a scapular flap containing only fascia and overlying fat can be an excellent choice. This can be obtained by harvesting the fasciocutaneous flap and deepithelializing or simply removing the skin, or incisions can be designed over the area to be harvested and thin skin flaps raised for exposure. The thickness of the elevated flap will dictate how much subcutaneous fat remains with the flap.

Osteocutaneous Flap
The scapular flap is the flap of choice when vascularized bone is required in combination with a large soft tissue defect. Bone stock is good and is best used straight, although osteotomies are possible with a good soft tissue cuff around the bone. The fibula is the best choice when multiple osteotomies are required. The advantage of the scapular flap over the fibula, however, is the large skin flap that can be carried without the need to skin graft the donor site and the relatively independent mobility of the skin and bone components, which is not the situation with the fibular osteocutaneous flap (see Chapter 3).

If bone stock is required as part of the dissection, the lateral border is favored for its greater diameter when compared with the medial osseous segment (3 cm thick versus 1.5 cm). A segment of bone is then marked: approximately 2 to 3 cm wide and 10 to 14 cm long is outlined.

Fig. 7C-6  A, The teres minor muscle and a portion of the teres major muscle are excised, exposing the periosteum on the dorsal surface of the scapula. Osteotomies are then performed, harvesting the lateral edge of the scapula. The serratus muscle inserting on the costal surface of the lateral border is cut, preserving its attachment to the inferior angle.
The segment starts just below the insertion of the long head of the triceps. The muscles can be directly incised, which releases the teres minor muscle and the superior portion of the teres major muscle, thus exposing the periosteum of the dorsal surface of the scapula. Osteotomies can then be performed.

The attachment of the serratus muscle to the inferior angle of the scapula is maintained. Once this is freed, dissection of the pedicle can be continued, as described previously. It is important to preserve the inferior angle to ensure shoulder stability. If the serratus and teres major muscles have been divided, they are reinserted through drill holes or suture anchors in the remaining scapula.

If the medial osseous segment is to be harvested, dissection proceeds down to the underlying muscles in this area.
The distal portion of the flap that overlies the medial part of the scapula is left attached, and the remaining more proximal portion is elevated. A medial osseous segment 10 to 12 cm long and 2 to 3 cm wide is marked, and after complete elevation of the skin paddle, this osseous segment can be harvested. The incision is made through the infraspinatus muscle, exposing the periosteum of the dorsal surface of the scapula. The greater rhomboid muscle must be released from its attachment on the medial border. The subscapularis and serratus anterior muscle attachments are also released from the anterior surface of this osseous segment.

The rhomboid and serratus anterior muscles must be reattached to the medial portion of the scapular bone through multiple drill holes.

**Bone-Only**

When only bone is required, an incision is made directly over the bone, and the dissection then proceeds as described for the osteocutaneous variant.
ARC OF ROTATION

Standard Flap

The arc of rotation of the flap is generally toward the shoulder or axilla, because the circumflex scapular vessels emerge from the triangular space laterally in the back. These vessels are the limiting point for rotation, and the reach of the flap will depend on the ultimate size of the flap designed.

Fig. 7C-7  The arc of rotation for any variant is around the circumflex scapular pedicle.
FLAP TRANSFER

Pedicle Flap
When the scapular flap is used as a regional tissue transfer, options include direct transposition from the donor site to the recipient site or subcutaneous tunnel transposition. This is largely based on the operating surgeon’s preference. Care must be taken when placing a flap through a subcutaneous tunnel that there is no compression on the vascular pedicle. With the skin flap completely elevated and side branches divided, rotation of 180 degrees is possible. With less skeletonization of the pedicle, less rotation is safely achievable.

Free Flap
If tissues are being used as a free tissue transfer, considerations of pedicle length and vessel diameter are crucial to determining how much dissection of the pedicle is required. Because these flaps tolerate ischemia well, it is not uncommon to harvest the flap and place it on the back table while the donor site is quickly closed. The patient can then be repositioned for the microsurgical portion of the procedure, if this is necessary.

FLAP INSET

Pedicle Flap
For pedicle flaps it is critical that the flap be inset without tension on the skin paddle and without kinking or torsion of the pedicle. For axillary use, a rotation of 180 degrees is not uncommon; it is therefore critical to dissect the pedicle of the flap into the triangular space to allow this degree of rotation without kinking. A parascapular design would require less rotation into the axilla and is preferred.

Free Flap
As a free tissue transfer, these considerations are less important. Once the flap and vessels have been harvested, inset is performed at the recipient site, again ensuring a tension-free closure without torsion, kinking, or tension on the microscopic anastomosis.

DONOR SITE CLOSURE

All Flap Variants
Primary closure should be the goal in most reconstructions. Occasionally, such a large amount of tissue is required that primary closure may not be obtainable. For these cases, if time allows, tissue expansion can be performed within the flap or in the periphery of the flap to assist in primary closure. Otherwise, donor sites that exceed 10 cm in width may require skin grafting and secondary expansion or closure. Once the tissues have been removed and the donor site requires closure, wide mobilization above the level of the fascia is recommended until a tension-free closure can be achieved. Scapa's fascia should be closed with sutures, and then the skin is closed. It is recommended that a drain be placed in the donor site, because seroma formation is a concern and can be exacerbated by early postoperative arm movements.
CLINICAL APPLICATIONS

This 39-year-old man underwent resection of a dermatofibrosarcoma protuberans of the cheek. In this moderately obese patient, the back provided the best donor site for the thin, pliable tissue needed for cheek resurfacing. A free scapular flap was performed, with primary closure of the back. One revision with liposuction and excision was required for the final result. A drawback of most reconstructive flaps not from the facial area is the mismatch of skin color and texture. Whereas women can often hide differences with cover makeup, men have a harder time hiding the differences, especially with facial hair growth surrounding the flap.

![Fig. 7C-8](image)

A, The preoperative defect requiring skin and some soft tissue replacement. There were no bony defects and no intraoral communication. B, The flap was harvested and anastomosed to the facial artery and vein. A small extension of the defect was required for the microscopic connection. C, The back donor scar is seen 1 year postoperatively. D, The final appearance after one revision with liposuction and skin excision (lateral view) and, E, oblique view is seen 3 years postoperatively. (Case supplied by MRZ.)
This 75-year-old man had an extensive squamous cell cancer of the scalp. He required wide resection and good soft tissue reconstruction so that he could undergo postoperative irradiation. Although large defects can often be skin grafted or reconstructed with muscle or with omental free flaps with skin grafting, any patient who will be undergoing postoperative radiation therapy should undergo reconstruction with a skin flap. Skin grafts do not tolerate irradiation, but skin flaps can, and often the final cosmesis is improved thanks to the effects of irradiation on the flap. Because of a poor Allen’s test, a radial forearm flap was ruled out and a scapular flap was performed. First, resection was performed and reconstruction was delayed until permanent clear margins were obtained. On postoperative day 4, margins were clear and reconstruction proceeded. The scapular flap was dissected to the subscapular system to lengthen the pedicle and reach the superficial temporal vessels. Ultimately, an A-V loop was required to anastomose to the facial vessels. The flap healed, and despite an area of local recurrence requiring a small skin graft, the patient and the flap tolerated postoperative radiation well.

Fig. 7C-9  A, Scalp wound with exposed bone. The periphery is marked for pathologic margins. Soft tissues including the outer table of skull were resected. B, The wound was dressed with Integra matrix wound dressing, awaiting final negative margins. C, A template of the wound was created and used in the design. Handheld Doppler was used to confirm the location of the circumflex scapular artery; the design included this point and both the transverse and the descending branches. The dotted line outlines the scapula for reference only.
The flap is elevated and pedicle length is maximized by following the vessels into the triangular space and dividing the thoracodorsal vessels. **E.** The flap inset. Exploration of the superficial temporal vessels showed inadequate size for anastomosis, so an A-V loop was constructed to anastomose to the facial artery and vein. A small skin graft was placed near the pedicle to decrease the pressure on the pedicle that was experienced with primary closure. **F.** The donor scar is seen 2 months postoperatively. **G.** The final result at 2 years. A small recurrence was resected and skin was grafted. No revisions were required, because the flap tolerated the radiation well, improving the final contour with contraction. (Case supplied by MRZ.)
This 77-year-old man had recurrent squamous cell carcinoma of the chin pad requiring a large soft tissue resection, including the lower lip and the anterior mandible with the floor of mouth. Although the fibula is preferred for anterior mandible reconstruction because it can be easily osteotomized, the flap does not supply enough soft tissue for these complex reconstructive needs. Rather than use a fibula and a second flap, a scapular osteocutaneous flap was chosen to reconstruct the entire defect. The scapula was osteotomized and the thin, pliable skin paddle was used for the floor of the mouth, lip, and chin pad. The relative independence of the skin and bone components allows this. The lower lip was supported with a fascia lata graft. Wide undermining allowed primary closure of the donor site, avoiding the need for a skin graft.

Fig. 7C-10  **A**, This defect was complex, with the floor of the mouth, full-thickness lip, chin pad, and anterior mandible removed. A reconstructive bar was placed before resection for correct contour, then replaced after the resection. **B**, Lateral view of defect. **C**, A template of the defect was used to design the flap. Such a large design will encompass both transverse and descending branches of the circumflex scapular artery so orientation is based more on areas of skin laxity. (Xs denote Doppler points; the dotted line the scapula; FOM is the planned floor of the mouth, and the arrow indicates the planned direction that the pedicle will go once inset.) **D**, The flap elevated with approximately 12 cm of lateral bone and the relatively independent skin paddle. The angle of the scapula was not harvested.
The bone was osteotomized in two locations to conform to the reconstructive plate. The muscular soft tissue cuff was maintained to vascularize the segments. A strip of fascia lata was used to support the lower lip reconstruction to maintain oral competence postoperatively. The fascia lata was inset into the modiolus bilaterally. Such support is required for such a large flap. Final inset of flap. The reconstruction is seen 1 month postoperatively. The patient has oral competence and intelligible speech. He has good lower lip position when he opens his mouth and a good aperture. The early lateral contour is good and will improve over time. (Case supplied by MRZ.)
This 29-year-old woman sustained a complex tibia-fibula fracture and had a nonunion and open wound requiring aggressive debridement and placement of methylmethacrylate beads. She needed a soft tissue flap to cover the beads and establish a well-healed soft tissue envelope so future bone grafting could proceed. The radial forearm donor site is not preferred in a woman, and she did not like the idea of an abdominal skin flap. She accepted the choice of a scapular flap, since she would not see the donor scar. A scapular flap was performed, and she ultimately underwent bone grafting. No flap revisions were required, and the donor site scar was acceptable to the patient.

**Fig. 7C-11**  
A, A grade III tibia-fibula fracture with exposed bony nonunion after debridement. A preoperative angiogram showed that all vessels to the foot were patent, so the posterior tibial system was prepared for recipient vessels. B, Flap design. The X marks the Doppler point of the circumflex scapular artery. Interestingly, laser angiography showed the perforators perfusing the dotted areas preferentially. A template from the leg helped design the flap to encompass the perforator and the areas it perfused best. C, Flap inset with one artery and two venous anastomoses to the posterior tibial system. The extra triangle of the flap over the anastomosis allows a tension-free closure over the anastomosis. D, Final flap result seen 4 months postoperatively, ready for secondary bone grafting. (Case supplied by MRZ.)
This 34-year-old man sustained a crush injury to his foot that ultimately required open transmetatarsal amputation. Soft tissue reconstruction was performed to maintain foot function. Although a muscle flap with skin graft was an option, it was thought that the wear and tear of shoes on his reconstruction would be problematic and that a skin flap would be better tolerated. A scapular flap was chosen because of the large amount of skin supplied and the acceptable donor location. Translocation of his back tattoo was not a concern. He underwent a large scapular flap for resurfacing of the foot. The large flap size required skin grafting of the donor site. He currently ambulates in a shoe with an orthotic device.

Fig. 7C-12  A, Original crush injury after demarcation. B, After transmetatarsal amputation and dressing changes. No further necrosis was evident, so soft tissue coverage was performed with a scapular flap. C, Inset of the flap with arterial anastomosis to the anterior tibial artery and a venous anastomosis to the lesser saphenous vein. D, Back donor site, which was skin grafted, seen 5 months postoperatively. (Note: Remaining bilateral back tattoo was removed from this photograph to protect patient identity.) E, Final result at 5 months postoperatively (AP view). F, Lateral view. (Case supplied by MRZ.)
This 39-year-old man had chronic hidradenitis of the right axilla, and conservative therapies had failed. After aggressive debridement and dressing changes, he was ready for reconstruction. It was thought that secondary healing or skin grafting would result in a functionally disabling contracture, and a soft tissue flap was planned. A parascapular flap is a natural flap for axillary soft tissue needs, since the tissue is readily available and the location of the vascular pedicle is a favorable point of rotation. In such cases, a parascapular design is preferred over a scapular design, because the degree of rotation of the flap is less.

Fig. 7C-13  A, Axillary defect 1 week after debridement of infected tissues and daily dressing changes. B, Parascapular flap design. X marks the Doppler point of the circumflex scapular artery. The flap was designed to the specifications of the defect and to allow primary closure of the donor site. C, Flap inset. Tension is borne by the donor closure. There should be no tension on the flap skin closure. D, The result is seen 2 months postoperatively with the arm abducted; E, at 6 months with the arm extended. F, Back donor scar at 6 months postoperatively. (Case supplied by MRZ.)
Pearls and Pitfalls

- Because this flap has excellent vascularity as long as the circumflex scapular vessel is included as it exits the triangular space, the surgeon should use the relaxed skin tension lines to produce the best scars and allow the most tension-free closures. Aligning the flaps on descending or transverse vessels is less critical. Laser angiography can provide further guidance for the design.
- For the axilla, the parascapular design is favored over the more transverse scapular design for axillary needs, because the arc of rotation is less.
- For soft tissue needs for the shoulder, a myocutaneous latissimus or thoracodorsal perforator (TDAP) flap may be a better choice, depending on the location of the defect, because these flaps have a larger arc of rotation and reach.
- Adipofascial flaps are an excellent choice when soft tissue fill is required, such as in reconstruction of a Romberg’s hemifacial atrophy or other conditions, such as radiation atrophy.
- The skin of a scapular flap is relatively hairless, but it will not be a good color match for the face.
- With preservation of the periosteum and a muscular cuff, osteotomies and shaping of the scapula can be performed. However, this is a second choice to the fibular flap for these purposes.
- This is a straightforward flap to dissect, with the potential for a long pedicle (10 to 12 cm) with large vessel diameters (3 to 4.5 mm).
- There is minimal morbidity and quick recovery to the fasciocutaneous and adipofascial flaps; it is important to reinsert any disinserted muscles when the bone is harvested for an osteocutaneous flap.
- Compared with other osteocutaneous flaps, such as those from the fibula and iliac crest, the skin paddle and the osseous segment can be manipulated separately, which allows greater flexibility in inset, depending on the bony and soft tissue needs.

EXPERT COMMENTARY
Michael R. Zenn

Indications
For distant tissue transfers, much of the use of the scapular and parascapular flaps has been replaced by the anterior lateral thigh (ALT) and radial forearm flaps, mainly because these flaps are easy to harvest, often in a two-team approach to reconstruction in which donor site and recipient site surgery are performed in parallel. Also, these flaps have been shown to have acceptably low donor site morbidity. The regional use of parascapular flaps, especially for axillary contracture of all causes, remains unquestioned.

Advantages and Limitations
So why bother with the scapular flap as a choice for free flap reconstruction? As reconstructive surgeons, we must have many weapons in our arsenal. Although the scapular free flap may be a second, third, or fourth choice in most cases, there are clearly times when it is the first choice (see Clinical Applications, Fig. 7C-10). Without a doubt, the scapular donor site

Continued
provides the largest surface area of flap, which is thin and pliable and is not encumbered by any muscle bulk, as is often required with the ALT flap. As a patient becomes more obese, the thighs and abdomen become less usable, and often the upper trunk is relatively spared from this lipodystrophy. Many of the patients requiring these free flaps are elderly, especially for head and neck applications, so sacrifice of the radial artery is problematic and is not recommended, discouraging the use of the radial forearm free flap. Also, donor site scarring is an issue, especially in younger patients and in women in general. Although a scar in the arm and leg can be noticeable and distressing to these patients, a back scar is better tolerated, since the patient cannot see it as well. For this reason, women prefer the superficial inferior epigastric artery (SIEA) or deep inferior epigastric perforator (DIEP) flap for reconstruction, because the donor scar is hidden in clothing. Finally, the occasional morbidity that can occur in the arm and leg involving neuropathy, paresthesia, and contracture rarely occur in the back, where the most common concern is poor scar quality.

Personal Experience and Insights
As I have attempted to fit the reconstruction to the patient more and more in my practice, I have offered the scapular flap more commonly as an alternative to the ALT and radial forearm and let the patient decide. And as I have matured as a microsurgeon, I am more comfortable harvesting a flap with the patient in the prone position and placing it on the back table while the donor site is closed and the patient is repositioned for the microsurgery. A fasciocutaneous flap is ideal for this approach, and I have never seen a failure of a free fasciocutaneous flap based on this delay of 1 hour or less.

Complications
The main complications associated with the use of this flap are ischemia of the flap and scarring at the donor site. Although the circumflex scapular vessels are quite large, the distribution of its perforating vessels is variable. The use of laser angiography can aid in the design of these flaps to ensure capture of the main areas of perfusion. In general, scars on the back can be wide, and sometimes preparing the patient for this inevitability can avoid the need for scar revision surgery.

Bibliography With Key Annotations

A multitude of local flaps have been suggested for lower extremity reconstruction. However, the gold standard for defect coverage remains free tissue transfer. In this regard, the scapular vascular axis is a well-established source of expendable skin, fascia, muscle, and bone for use in free flap reconstruction of defects requiring bone and soft tissue in complex three-dimensional relationships. Composite bone and soft tissue flaps derived from the subscapular vascular axis include the osteocutaneous scapular flap, the “latissimus/bone flap,” and the thoracodorsal artery perforator-osteocutaneous osteocutaneous flap. Patient outcomes after reconstruction of lower extremity defects with composite free flaps from the thoracodorsal system were analyzed. The authors demonstrated the execution of technical refinements on free composite flap transfers based on the thoracodorsal vascular axis, thus resulting in a stepwise reduction of donor site morbidity.


Composite free flaps that are available for reconstructions of the head and neck include those from the fibula, iliac crest, radial forearm, and scapula, but only that from the scapula precludes two-team
operating and consequently adds a further 2 to 3 hours to the operating time. The authors clarified the indications for the subscapular system of composite flaps and discussed their unique properties in terms of reliability of the bony segment, their resistance to atherosclerosis, and the diversity of the skin and muscular components that are available. They have had favorable results in composite resections of the anterior mandible that required substantial resections of the anterior tongue. The authors presented a consecutive series of 46 patients, documenting the use of this option in routine head and neck practice.

In extensive oropharyngeal resections that require a segmental resection of the mandible, the skin island is reliable and provides sufficient bulk to reduce the risk of dehiscence and maintains a narrowed oropharynx to improve speech and swallowing. In reconstructions of the midface, a combination of the latissimus dorsi and the scapula that is based on the angular branch of the thoracodorsal vessel (thoracodorsal angular flap) allows a long pedicle, and adequate muscle and bone for high and low maxillectomy defects.


Microsurgical development has recently focused on the perforator paradigm and primary thinning. Existing perforator flaps may require intramuscular dissection or lack reliable surface markings, whereas traditional scapular/parascapular flaps have low donor morbidity and reliable anatomy, but can be excessively bulky. Clinical application of a new flap based on a perforator from the circumflex scapular axis (CSA) has recently been published, but the vessel's anatomy has not been adequately characterized. The authors dissected the CSA in 115 sites in 69 cadavers and measured the number, external vessel diameter, and site of origin of perforators relative to the CSA bifurcation. Color Doppler ultrasound was used to delineate the CSA and its perforators bilaterally in 40 volunteers. The number, origin relative to CSA bifurcation, diameter, length, and flow velocity of cutaneous perforators were determined. A CSA perforator was always present, running into the subdermal plexus, arising within 2.4 cm of the bifurcation. The authors definitively described the anatomy of the perforator from the circumflex scapular artery on which a new flap has been based. Its origin and dimensions are anatomically and radiologically reliable. The flap has certain potential benefits over existing perforator flaps.


Based on initial clinical observations, cadaveric, and radiologic studies, the authors described a new, thin, perforator flap based on the circumflex scapular artery (CSA). A perforator vessel was found to arise within 1.5 cm of the CSA bifurcation (arising from the main trunk, or the descending branch). The perforator arborizes into the subdermal vascular plexus of the dorsal scapular skin, permitting the elevation and primary thinning of a skin flap. This thin flap was employed in five clinical cases to reconstruct defects of the axilla. No intramuscular perforator dissection was required; pedicle length was 8 to 10 cm and vessel diameter 2 to 4 mm. There were no significant perioperative complications or flap failures, all donor sites were closed primarily, patient satisfaction was high, and initial reconstructive aims were achieved in all cases. Surgical technique and the vascular basis of the flap were described.


The authors reviewed microsurgical free flap reconstructions to amputation stumps of the upper as well as the lower extremities in seven male and two female patients. Indications included preservation of length after trauma in six patients and cure of local infection in two patients. In one patient an extensive defect after resection of a recurrent shoulder sarcoma required use of a complete arm fillet free flap for tumor reconstruction. Microvascular free flaps used included four scapular flaps, two fillet flaps from the amputated extremity, one anterolateral thigh flap, and one lateral arm flap. Seven of nine patients were fitted with a prosthesis and underwent occupational therapy resulting in ambulatory and improved functional status. Microvascular reconstruction is indicated in emergency settings as well as for elective reconstruction of amputation sites. Using uninjured “spare parts” of the amputated extremity should be considered. Elective reconstruction is performed preferably with free flaps based on the subscapular vascular system.
Fairbanks GA, Hallock GG. Facial reconstruction using a combined flap of the subscapular axis simultaneously including separate medial and lateral scapular vascularized bone grafts. Ann Plast Surg 49:104-108; discussion 108, 2002. The authors presented a case report in which a conjoined combined free flap consisting of four free tissue transfers based on the subscapular axis was used in simultaneous reconstruction of a gunshot wound to the face. This included a medial scapular osteofasciocutaneous flap for the mandible, a lateral scapular osseous flap for the anterior maxilla, a serratus anterior muscle flap for the cheek, and a separate latissimus dorsi musculocutaneous flap for the forehead. This flap was successful and provides another alternative to the resolution of complex problems needing multiple areas of both soft tissue coverage and vascularized bone graft.

Hanasono MM, Skoracki RJ. The scapular tip osseous free flap as an alternative for anterior mandibular reconstruction. Plast Reconstr Surg 125:164e-166e, 2010. The authors described the successful use of scapular tip osseous free flap for anterior mandibular reconstruction in seven patients with peripheral vascular disease, which precluded fibula free flap harvest. These cases are novel in that the inferior angle of the scapula is oriented transversely and used to recreate the anterior mandible, obviating the need for bony osteotomies. This flap is based on the angular branch of the thoracodorsal artery rather than the circumflex scapular artery, which is the traditional blood supply of the scapular flap.

Hwang JH, Hwang K, Bang SI, et al. Reliability of vascular territory for a circumflex scapular artery-based flap. Plast Reconstr Surg 123:902-909, 2009. The authors evaluated the cutaneous vascular territories of the circumflex scapular artery and the areas supplied by perforators from neighboring anatomic vascular territories. They also defined the safety limits of circumflex scapular artery–based flaps by means of fresh cadaver injection studies. A total of 15 dorsal thoraxes from eight fresh cadavers were used in this study. After saline irrigation, contrast medium was injected into the subclavian artery of each specimen. Each full-thickness specimen of the posterior hemithorax was then radiographed to characterize vascular networks. The primary zone of the circumflex scapular artery was calculated to be $93.8 \pm 16.1$ cm, which occupies a region smaller than that of the scapula. However, by capturing the secondary zone, which was composed of the territories supplied by adjacent perforators of the thoracodorsal artery, the dorsal intercostal artery, and the transverse cervical artery, potential flap survival dimensions extended beyond the scapular region. In fact, the potential zone was increased to $307.7 \pm 55.3$ cm, which extended beyond the scapular spine, the inferior angle of the scapula, the posterior axillary line, and close to the midline of the back.

Jaminet P, Pfau M, Greulich M. Reconstruction of the second metacarpal bone with a free vascularized scapular bone flap combined with nonvascularized free osteocartilaginous grafts from both second toes: a case report. Microsurgery 31:146-149, 2011. In this report, the authors presented a case of a giant cell tumor of the second metacarpal bone. The tumor was treated by en bloc resection of the distal portion of the second metacarpal with adjacent interosseous muscle. Reconstruction was achieved using a free vascularized scapular bone flap with nonvascularized free osteocartilaginous grafts from both second toes. Structural integrity and metacarpophalangeal joint motion were preserved, with good functional result. A brief review of the literature was presented.


Labow BI, Rosen H, Pap SA, et al. Microsurgical reconstruction: a more conservative method of managing large scalp defects? J Reconstr Microsurg 25:465-474, 2009. Scalp reconstruction is a challenging problem requiring attention to the cause, size, and condition of the defect to formulate an optimal reconstructive plan. Although many “conservative” options have been described even for large wounds, the use of local flaps or split-thickness skin grafts (STSGs) may actually result in the need for multiple procedures, prolonged wound care, increased patient discomfort, and an unsatisfactory aesthetic result. The authors reviewed 37 patients who had received a total of 38 free flaps for scalp defects of 100 cm$^2$ or more secondary to a broad range of etiologic factors. There were 24 males and 13 females, with a mean age of 47.4 years (range 7 to 83 years). The mean
scalp defect size was 356.2 cm² (range 130 to 675 cm²). More than half the patients had previously undergone local flap reconstructions or STSGs that had failed (n = 20; 54.1%). Latissimus dorsi muscle or myocutaneous flaps were the most commonly used free flaps in this series. Rectus abdominis muscle, scapular, radial forearm, and omental donor sites were also used. There were a total of 10 complications among 10 patients (27%). Two patients (5.4%) had major complications, and eight patients (21.6%) had minor complications. Four complications (40%) were in patients who had received radiation therapy. Definitive closure was achieved using free tissue transfer in 95% of patients who had previous attempts at closure using local options. These results demonstrate that free tissue transfer is a safe and highly efficient reconstructive option to manage large scalp defects under a variety of conditions. In large complex scalp wounds, especially in patients receiving radiation, microsurgical reconstruction should be the preferred method of management.


Reconstruction of the large lumbar defect is a challenge for plastic surgeons. The authors reported their experience with the reverse latissimus dorsi myocutaneous flap for the coverage of large lumbar wounds in two oncologic patients. Meanwhile, a pedicled ascending scapular flap was used to aid the donor site closure of the myocutaneous flap. This allowed easy closure of both the donor sites and minimized donor site morbidity. This procedure is highly reliable, and in the authors’ opinion, it is the first option in reconstruction of large lumbar defects, particularly when a large surface coverage is needed.


The authors conducted a retrospective review of patients who underwent scapular free flap reconstruction between 1997 and 2007. Osteocutaneous and fasciocutaneous flaps were included. Defect analysis and complications were also reviewed. Sixty procedures were performed, including 31 osteocutaneous and 29 fasciocutaneous flaps. Most fasciocutaneous flaps were used for large defects of the lateral skull base and face (70%). The skin paddle dimensions ranged from 4 by 3 to 15 by 10 cm. All osteocutaneous flaps were used for mandibular reconstruction. The length of the bony defects ranged from 4 to 12 cm. Eleven patients required osteotomies. In most cases, the facial or external carotid arteries and internal jugular or facial veins were selected as recipient vessels. A vein graft was required in four cases. The total flap failure rate was 5%. Seven patients who had osteocutaneous flaps had medical complications, including one mortality. Scapular free flaps are reliable options. Fasciocutaneous applications are suitable for defects requiring facial contouring or complex skull base defects. Osteocutaneous flaps are acceptable options for patients with comorbidities requiring bony reconstructions. The flap complication rates were acceptable, even in medically higher-risk patients.


Inappropriate treatment of axillary burns frequently results in adduction contractures. In this clinical study the authors reviewed 32 patients with different types of axillary postburn adduction contractures. They used a variety of surgical treatments for reconstruction of axillary contracture releasing defects, such as simple grafting, Z-plasties, and locally pedicled flaps. Among these alternatives, they used the scapular island flap most frequently. In addition to conventional harvest of this flap, extension of its pedicle up to the subscapular ramification by passing it through the triangular space allowed its transfer even to the anterior axillary line defects in a vertical orientation without pedicle kinking. In conclusion, the island scapular flap is a good choice for reconstruction of all types of axillary contractures, releasing defects with satisfactory results in terms of function and cosmesis.


The authors presented their study in which they assessed the metabolism of the bony segments of osteocutaneous free flaps, including lateral as well as medial scapular crests, by 18F-fluoride PET/CT examinations and evaluated donor site morbidity. Twenty patients were included in the study; in
10 patients, osteocutaneous free flaps were harvested that included lateral as well as medial scapular crests. Seven days after surgery, an 18F-fluoride PET/CT examination was performed to assess the metabolism and viability of the bony segments. In the other 10 patients, flaps were harvested that only included the lateral scapular crest. One and 6 months after surgery, all patients were asked to fill in the disabilities of the arm, shoulder, and hand (DASH) questionnaire. In the 10 free flaps that included lateral as well as medial scapular crests, 18F-fluoride PET/CT examinations revealed metabolism and viability of both bony segments. The DASH scores for the two patient groups did not differ significantly at 1 and 6 months after surgery. It seems that scapular osteocutaneous free flaps adopting lateral as well as medial scapular crests are a viable option for mandibular reconstruction and may be an alternative to the fibular double barrel.

Oyama T, Ohjimi H, Makino T. Bilayer reconstruction for Parry-Romberg syndrome: using a free circumflex scapular artery-based adipofascial flap for both the buccal fat pad and subcutaneous fat. Ann Plast Surg 2011 Mar 2. [Epub ahead of print]

When using a free flap to reconstruct a facial deformity caused by Romberg's disease, it is important to prevent the flap from sagging after the operation. The authors reported a new method of reconstructive surgery using a free subscapular adipofascial flap to prevent this problem. Three women (27, 28, and 34 years of age) with Parry-Romberg syndrome underwent microsurgical free scapular flap transfer for buccal defects. This operation requires making a gingivobuccal sulcus incision and forming a pocket for buccal fat reconstruction by dissecting over the periosteum of the maxillary bone. Preauricular and submandibular incisions are made to create a subcutaneous pocket for flap transfer. After the subscapular flap is elevated, the authors use its angiogram to observe its vascular pattern. The flap is separated to preserve the main blood vessels horizontal lower branches. The subcutaneous adipose tissue layer uses the horizontal branch, and the buccal fat pad layer the lower branch. Postoperatively, the adipofascial flaps were in good condition and without complications. Six months after the first operation, revision surgery was performed on one patient. No cases showed sagging of the cheek, and in every case the overall appearance of the buccal region improved significantly.


Reconstruction of head and neck burns is challenging, traditionally involving skin grafting and local flaps. Free flaps have improved in versatility and variability in recent years, and are now among the techniques used for burn reconstruction. Thirty-six free flaps for 32 patients with cervicofacial burns were reviewed retrospectively over a 17-year period (1989 to 2005) to determine indications, methods, and outcomes. The mean patient age was 31 years. Thirteen flaps were transferred to the neck and 23 to the face. The main indication was contractures or hypertrophic scarring, followed by exposed bone or cartilage. The majority of flaps were transferred for secondary reconstruction. The free flaps most frequently used were the anterolateral, scapular/parascapular, and radial forearm. Fourteen were prefabricated, 1 was prelaminated, and 15 were tissue-expanded. Thirty-four flaps were successful. There were no deaths, two donor site complications, a 17% tip necrosis rate, and a 6% flap infection rate. The median hospital stay was 6 days after free flap transfer. Patients were followed for at least 1 year; 64% of flaps needed further debulking or sculpting. Free tissue transfer is a valuable tool in head and neck burn reconstruction. It can be used safely and effectively with minimal morbidity in selected patients.


The vascularized scapular bone free flap is popular in mandible reconstruction, but it is less commonly used as a pedicled flap to reconstruct the upper humerus. The authors analyzed their experience in eight patients with pedicled scapular crest flaps in humerus reconstruction and compared their results with cases reported in the literature. They considered the age at surgery, time elapsed before reconstruction, time required to obtain solid bony union, the operative indication, the osteosynthesis procedure used,
and whether circumflex scapular vessels or angular vessels were used. Flaps were pedicled either on circumflex scapular vessels (three) or angular vessels (five). The mean size of the scapular bone used was 9.4 cm (range 7 to 11 cm). The authors used a covering flap in seven patients. All flaps survived and bone healed in 3 to 6 months (mean 3.75 months). There was one accidental secondary fracture 1 year after reconstruction. For a vascularized reconstruction of the upper humerus, the pedicled scapular bone flap is a valuable option especially if a composite reconstruction is needed. For short humerus stump lengthening, this flap seems to provide a very satisfactory solution.


Since their first review of microsurgical correction of facial contour deformities in 19 patients with craniofacial malformations, the authors have treated an additional 74 patients (total 93). The authors reviewed indications, choices, safety, efficacy, complications, and technical refinements. A treatment algorithm was presented. Microsurgical flaps have markedly improved the authors’ ability to restore craniofacial contour in patients with craniofacial malformations. In selected patients, the authors chose primary midface augmentation with free vascularized tissue to restore form and function. Microsurgical flaps in patients with craniofacial malformations are safe, effective, and reliable.


Deformities of a totally burned face present a profound challenge to the reconstructive plastic surgeon. Skin grafting has been used traditionally for resurfacing with limited success, especially when the burns were so severe the deeper structures were destroyed. Total face reconstruction, using bilateral extended scapular free flap, has been reported previously for severe deformities following an extensive facial burn. Although this method obtained better aesthetic and functional results than skin grafting, the donor site morbidity was relatively high, with a large scar that extended across the entire back. In addition, the nose needed to be reconstructed separately with a forehead flap or free radial forearm flap. The authors presented a case in which a patient’s totally burned face was reconstructed successfully with a single free-expanded flap. A 54-year-old man sustained a severe facial burn with gasoline. The burn involved the face, anterior neck, anterior chest, and bilateral upper extremities. Sequential debridement and skin grafting were required to close the burn wound. A tissue expander was inserted in his left back before the facial reconstruction. Six months after insertion of the tissue expander, the left dorsal skin was transferred to the face as one large flap, size 28 by 27 cm, with three sets of vascular anastomoses. The flap totally survived with abundant tissue at the central area to reconstruct the nose. With five complementary procedures, including a costal cartilage graft, the shape of the nose was restored, and acceptable functional and aesthetic results were obtained. This method did not require a separate tissue transfer for nasal reconstruction. To their knowledge, this was the first case of successful reconstruction with one flap for total face reconstruction that included the nose.


To treat lower extremity osteomyelitis resulting from trauma, bone and soft tissue can be grafted at the same time using microsurgical techniques. The authors investigate the use of chimeric flaps based on thoracodorsal vessels incorporating vascularized scapular bone and latissimus dorsi myocutaneous flap to reconstruct bone and soft tissue defects of the lower leg due to osteomyelitis. Ten patients with lower extremity bone and soft tissue defects from osteomyelitis were treated. Vascularized scapular bones were raised on the angular branch of the thoracodorsal artery. Latissimus dorsi myocutaneous flaps were elevated simultaneously to reconstruct the soft tissue defects. All patients tolerated the procedure well. One patient developed an early venous thrombosis, which was successfully treated by thrombectomy. Mean follow-up time was 7 years and 8 months. Bone union without refraction was observed in all patients. The mean time required for bone union after surgery was 13.5 weeks. Donor site morbidity
was minimal. Chimeric flaps based on thoracodorsal vessels incorporating vascularized scapular bone and latissimus dorsi myocutaneous are safe and effective in the repair of lower extremity bone and soft tissue defects caused by osteomyelitis.


The authors investigated the use of serial autologous fat grafting to restore soft tissue contour in craniofacial microsomia patients. Patients with moderate to severe craniofacial microsomia were divided into two groups. Ten microvascular free flap patients underwent reconstruction with inframammary extended circumflex scapular flaps at skeletal maturity. Twenty-one patients had fat grafting during multiple staged operations for mandible and ear reconstruction. Sex, age, severity of deformity (determined by OMENS [orbital deformity, mandibular hypoplasia, ear deformity, nerve involvement, and soft tissue deficiency] classification), number of procedures, operative times, and augmentation volumes were recorded. A digital three-dimensional photogrammetry system was used to determine “final fat take” and symmetry (affected side versus unaffected side). Physician and patient satisfaction were elicited. Microvascular free flap and fat grafting groups had similar OMENS scores, 2.4 and 2.3, and similar mean prereconstruction symmetry scores, 74% and 75%, respectively.


Pediatric axillary postburn contractures one of the most challenging problems that follow treatment of the upper extremity burns. The authors prefer to use scapular flaps for surgical treatment of pediatric axillary contractures instead of skin grafting or Z-plastics. In this clinical study the authors presented 13 pediatric cases treated with scapular island flaps. In pediatric scapular flap cases, the technique they used was to extend the flap’s pedicle dissection to the level of bifurcation of subscapular artery. Bypassing the flap triangular space allowed them to cover the anterior part of the axillary contractures. They observed that the scapular flap repairs have many benefits to skin grafting including no recurrence of contracture and stable coverage of the shoulder joint. The other advantages of scapular island flap are that the donor site is closed primarily, and it provides an adequate amount of pliable skin while not compromising the function and range of motion of joints.


Free tissue transfer has become the dominant reconstructive tool for segmental defects of the mandible, except in case of severe peripheral vascular disease. In these cases, the authors propose to use the osteomuscular dorsal scapular (OMDS) flap as an alternative technique. This flap is pedicled on the dorsal scapular vessels with the harvesting of the medial border of the scapula and the lateral part of the rhomboid muscles. The main disadvantages of the OMDS flap are the impossibility of placing implants in the bone that have been harvested because of its thickness and the lateral position that has to be changed to supine to allow access for resection of the tumour.


Composite tissue defects of the mandible and maxilla, after resection of head and neck malignancies, osteoarthrodieses, malformations, or traumas, cause functional and aesthetic problems. Today microvascular free flaps represent the main choice for the reconstruction of these defects. Among the various flaps proposed, the scapula flap has favorable characteristics that make it suitable for bone, soft tissue, or combined defects. Although the fibula flap and the deep circumflex iliac artery flap remain the first choice for bone reconstructions of the mandible and maxilla, the scapula flap has some features that make its use extremely advantageous in some circumstances. In particular, the authors advocated the use of the osteomuscular latissimus dorsi–scapula flap for reconstruction of large-volume defects involving the bone and soft tissues, whereas fasciocutaneous parascapular flaps represent a valid alternative to forearm flap and anterolateral thigh flap in the reconstruction of soft tissue defects.

A series of 25 osteocutaneous scapular flaps was performed from August 2000 through January 2005. Of these 25 flaps, 7 procedures of scapular bone solely vascularized by the angular artery and vein were performed to reconstruct head and neck defects. The angular vessels were used to reach the neck for anastomosis in midfacial reconstruction (2), to carry a separate second bone flap in complex oromandibular defects (2), and to reach the contralateral neck for anastomosis in through-and-through oromandibular defects encompassing overlying facial skin (3). Postoperative bone scans revealed all bone segments to be vascularized. The pedicle length originating from the circumflex scapular vessels varied from 6.7 to 9.0 cm (mean length 7.5 cm). The pedicle length of the angular vessels varied from 13.0 to 15.0 cm (mean length 14.1 cm), a mean length of 6.6 cm longer than the circumflex scapular flap. Vein grafts were not necessary to perform remote anastomoses with the additional pedicle length. The angular vessels can reliably supply the scapula. Use of the angular vessels over the circumflex scapular vessels increases the bone pedicle length by a mean length of 6.6 cm (88%) and is a useful technique to avoid vein grafting for remote anastomosis.


Penile reconstruction has always been a challenging problem for plastic surgeons; patients present with severe congenital deformities and gender dysphoria, or they may have suffered penile loss because of trauma, self-amputation, malignancy, and so on. Since 1936, when Bogoras first constructed a total penis, attempts have been made by different techniques, including skin flaps or myocutaneous flaps. And with development of free tissue transfer and microsurgical techniques, various free skin flaps, such as the radial free forearm flap, the superficial inferior epigastric artery flap, the superficial circumflex iliac artery flap, have been attempted for phallic construction, with the goal of functional (including a competent neourethra that allows voiding while standing and sexual intercourse) and cosmetic result. The purpose of their study was to evaluate the scapular free flap and implantation of malleable penile prosthesis for penile reconstruction. Twenty patients with penile loss underwent reconstruction with a one-stage procedure by transferring scapular flap and implantation of a malleable penile prosthesis. The patients ranged between 21 and 36 years old. Of these patients, 12 had penile amputation resulting from an electric accident; the other 8 were self-amputated. All the flaps remained 100% viable postoperatively. Follow-up ranged from 1 to 5 years. There were no cases of urethral fistula, urethral stenosis, prosthesis extrusion, or infection. The reconstructed penis yielded satisfactory function and aesthetic appearance. The scapular free flap is an ideal flap that achieves satisfactory function and aesthetic appearance for penile reconstruction because of its adequate amount of tissue, reliable vascularity, acceptable donor site morbidity, and reliable blood supply.


The authors described an algorithm for reconstruction of both the soft tissue and skeletal components of severe postburn neck deformities. The critical functional and aesthetic importance of the cervicomental angle is emphasized. The neck is subdivided into 3 anatomic subunits: (1) lower lip/chin subunit, (2) submental subunit, and (3) anterior neck subunit. After release of contractures, platysmaplasty is performed to prevent recurrence and to deepen the cervicomental angle. In cases where chin retrusion is present, sliding genioplasty is performed. The 3 subunits are resurfaced individually by skin grafts and free flaps. The combined scapular and parascapular bilobed free flap is an ideal flap for cases involving 2 subunits. Fifty patients with severe postburn neck contractures were treated. After excision and release of scar, 47 (94%) patients underwent platysmaplasty, and 12 (24%) patients underwent sliding genioplasty. Defects were covered with skin grafts alone in 20 (40%) patients, with free flaps only in 22 (44%) patients, and with a combination of skin grafts and free flaps in 8 (16%) patients.
ANATOMIC LANDMARKS

<table>
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<tr>
<th>Landmarks</th>
<th>Lumbar back, from midline to midaxillary line.</th>
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<td>Size</td>
<td>$15 \times 24$ cm; 10 cm width or less for primary closure.</td>
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<tr>
<td>Composition</td>
<td>Fasciocutaneous.</td>
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<td>Dominant Pedicle</td>
<td>Lumbar perforating arteries from L1 to L5.</td>
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<td>Nerve Supply</td>
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Section 7D

POSTERIOR TRUNK

Lumbar Perforator Flap

CLINICAL APPLICATIONS

Regional Use
- Back
- Buttock

Specialized Use
- Breast reconstruction
ANATOMY OF THE LUMBAR PERFORATOR FLAP

Lumbar muscles and arterial perforators

Lower back sensory nerves

Cross-section of lumbar region

Fig. 7D-1

Dominant pedicle: Lumbar perforating arteries (L1-L5)
ANATOMY

Landmarks  The lumbar area, defined by the lumbar spinal bodies, from the midline to the midaxillary line.

Composition  Fasciocutaneous.

Size  15 × 24 cm maximally. As with most flaps of the back, in most patients primary closure can be obtained with a width of 10 cm or less. In patients with skin laxity, this can be greater. Otherwise, the donor site can be skin grafted.

Arterial Anatomy

Dominant Pedicle  *Lumbar perforating arteries*

**Regional Source**  Aorta (L1 to L4); iliolumbar arteries (L5).

**Length**  2 cm.

**Diameter**  1 mm.

**Location**  Perforators from the upper three lumbar vertebral bodies run between the erector spinae and the quadratus lumborum muscles. The last two pairs of perforators run in front of the quadratus lumborum muscles just lateral to the erector spinae musculature. Each lumbar artery gives off a perforating vessel. The second and fourth perforators generally are the largest.

Venous Anatomy

Accompanying venae comitantes with the perforators.

Nerve Supply

**Sensory**  Superior cluneal nerves (L1 to L3).
VASCULAR ANATOMY OF THE LUMBAR PERFORATOR FLAP

Fig. 7D-2  A, Arterial system and B, artery and bone are shown in these posterior views of three-dimensional reconstructions of the pelvic region from a human cadaver angiographic injection specimen. (1 Lumbar artery; 2 superior gluteal artery.) C, Interior view and D, angiogram of the soft tissues of the gluteal region. (L3 and L4, Third and fourth lumbar arterial perforators; 1, anterior branch of the fourth lumbar arterial perforator; 2, posterior branch of the fourth lumbar arterial perforator; 3, ascending branch of the superior gluteal artery; IGA, inferior gluteal artery; SGA, superior gluteal artery; green arrow, anterior superior iliac spine; red arrow, greater trochanter; blue arrow, gluteal fold.)
FLAP HARVEST

Design and Markings
Lumbar artery perforators are first localized using Doppler ultrasound. The flap design then encompasses this Doppler point. The margins of the flap can run from midline to midaxillary line, depending on the reconstructive need. Elliptical patterns are most common, since they aid in closure. Depending on the location of the defect, a second lumbar perforator is preferred for dorsal defects; the fourth lumbar perforator is preferred for sacral defects.

**Patient Positioning**
The patient is placed prone or in the lateral decubitus position.
GUIDE TO FLAP DISSECTION

Dissection begins laterally at the distal end of the flap. The incision is deepened down to lumbar fascia, which is elevated with the flap. Dissection proceeds carefully until the perforating vessels are identified. With identification of the perforator, the entire flap may then be incised and dissection proceeds completely around the perforator. The muscle can then be split and further dissection of the pedicle can be performed 2 to 3 cm to aid in mobilization and the arc of rotation of the flap. Since the vessels travel obliquely and anteriorly from the lateral edge of the rectus spinæ muscle, excessive skeletonization of the pedicle does not lengthen the flap reach. For large defects of the sacrum, bilateral perforator flaps can be designed.

FLAP VARIANT

Free Flap

Lumbar artery perforator flaps have been described for autologous breast reconstruction, especially when abdominal tissues are not available. Here the dissection of the pedicle is continued until a large enough diameter of artery and vein can be exposed for coaptation in the chest. A position change is also required, because the flap is harvested in either the prone or lateral decubitus position, and the flap must be inset and shaped with the patient supine. Preoperative CT angiography or MRA studies can often be helpful to determine whether dominant vessels are available in this area for such procedures.
**ARC OF ROTATION**
The arc of rotation of flaps will depend on the location of the pedicle. Most flaps are turned toward the midline with a rotation of 90 degrees. For rotation to 180 degrees, some skeletonization of the pedicle must be performed to allow the torsion of the pedicle to be distributed over a longer length.

**FLAP TRANSFER**
Flaps are transposed into the defect to be reconstructed. Although they may be tunneled subcutaneously, it is recommended to connect the donor site and the recipient site to take any unnecessary pressure off the pedicle of smaller perforating vessels and to allow for postoperative edema that could compromise flow in a subcutaneous tunnel.

**FLAP INSET**
Lumbar flaps should be inset with a tension-free closure. All tension should be borne by the closure at the donor site. Drains are recommended for a few days until the amount of drainage has diminished.

**DONOR SITE CLOSURE**
Primary donor site closure should be possible in flaps 10 cm in width and possibly wider. In some patients, undermining of the donor site, especially on the side away from the flap rotation, will allow further subcutaneous advancement and help minimize tension on closure.
CLINICAL APPLICATIONS
This 56-year-old woman had a history of lobular carcinoma of the left breast and had undergone bilateral mastectomy with tissue expander/implant reconstruction 7 years earlier. Her complaints included chronic discomfort associated with her implants and recurrent low-grade cellulitis on the left. Additional concerns included poor central projection, asymmetry, lack of inframammary fold definition, and an overall poor aesthetic. Both breast implants were removed and capsulectomies performed, and her breast volume was reconstituted with an initial lumbar artery perforator flap. She subsequently underwent deep inferior epigastric perforator flap addition on both sides as a stacked overlay to her lumbar artery perforator flaps for added volume and skin paddle increase.

Fig. 7D-6  A, Preoperative and B, postoperative views. Bilateral implant removal and capsulectomies were performed, followed by redo breast reconstruction with lumbar artery perforator (LAP) flaps and subsequent deep inferior perforator (DIEP) flap stacked overlay of her LAP flaps to achieve desired volume and skin replacement. C, The hip donor site is seen before and D, after LAP flap harvest, with associated truncal contour change. (Case courtesy Frank J. DellaCroce, MD.)
This 40-year-old woman had a strong family history of breast carcinoma. She was seen in consultation for autologous reconstructive options before undergoing bilateral prophylactic mastectomies. Lumbar artery perforator flaps were used for immediate reconstruction to reconstitute her breast volume.

Fig. 7D-7  A, The patient is seen preoperatively and B, postoperatively after bilateral prophylactic mastectomies with immediate lumbar artery perforator (LAP) flap reconstruction. C, Before and D, after views of the hip donor site following LAP flap harvest, with associated truncal contour change. (Case courtesy Frank J. DellaCroce, MD.)
Pearls and Pitfalls

- The second or fourth intercostal perforator should be used preferentially, because these tend to be the largest perforators.
- For a large defect of the midline, bilateral flaps should be considered.
- Gluteal perforator flaps may be appropriate in cases in which a good lumbar perforator cannot be found on Doppler examination.
- Sensate flaps are possible by preserving the cutaneous nerve that travels with the perforator.
- Because of variable anatomy and small vessel size, the use of the lumbar perforator flap as a free tissue transfer is a distant third or fourth choice for reconstruction.

EXPERT COMMENTARY
Frank J. DellaCroce

Advantages and Limitations
The lumbar artery perforator flap is rarely used in the clinical setting. Its anatomy tempts with the promise of a large composite of fatty tissue, but the underlying vascularity is challenging to deal with. It may be used as both a regional flap and a free flap. The former is a more practical application, because rotating the flap around the pedicle’s exit point is a surgical exercise that may be attempted by a reconstructive surgeon with even modest experience. Employing the lumbar perforator flap as a free tissue transfer is made difficult by the short pedicle (2 to 3 cm) and the fact that the artery remains small (approximately 1 mm) throughout its length.

With respect to the use of the flap for breast reconstruction, it has the potential to provide a relatively large amount of fatty volume, even in individuals with a slight build. This fact may draw the breast reconstructive surgeon to consider its use. The lordotic curvature of the low back in this area provides a depressed deep surface to the flap harvest site and the convexity of the “love handle” on the superficial aspect means that the fatty depth is substantial in most patients at this level. Despite this, the overlying skin tends to be thick and inelastic, so the ratio of skin to fat is low. This can limit utility for breast reconstruction, particularly for delayed reconstructions. An attempt to harvest 10 cm or more of skin width with this flap will be met with a closure that is akin to a drumhead over an underlying valley. The need to maintain a drain tube in place for a significant period and the likelihood of chronic seromas are other significant considerations.

Recommendations
Planning
Doppler examination, cross-referenced with angiography (CTA/MRA), provides accurate determination of the location of the lumbar perforators (Fig. 7D–8). The skin pattern and associated bevel of the underlying fat may be tailored accordingly (Fig. 7D–9). Patient positioning may be either prone or lateral decubitus.
Posterior Trunk

7D: Lumbar Perforator Flap

Fig. 7D-8  CT angiography demonstrating the course of the lumbar perforator into the overlying soft tissue.

Fig. 7D-9  Preoperative markings for bilateral lumbar perforator free flaps with associated Doppler signal points.

Technique

As the dissection proceeds through the subcutaneous fat, I prefer to elevate the flap superficial to the fascia underlying the fat. Although this makes the identification and skeletonization of the perforators more difficult, it avoids removing the lumbar fascia with the flap. Removing the fascia in this region introduces the potential of a lumbar hernia, which despite being a rare phenomenon, is best avoided. Therefore I prefer to think of this flap as an adipocutaneous flap rather than a fasciocutaneous flap. As the dissection progresses around the perimeter of the flap, the superior cluneal nerves will be encountered over the superior border. These nerves are of impressive size, and in my experience, transection of them at their penetration point causes substantial numbness across the donor site.

When the perforating vessels are encountered, they will be tightly bound in fascial tissue, and the dissection plane under the flap will be somewhat difficult to navigate. Working through these challenges allows skeletonization of the pedicle, which can be impressive in its overall size. As the surgeon will soon discover, the majority of this size is a consequence of the vein’s diameter rather than that of the artery. Preserving the fascia and splitting it around the perforator’s surface allows the vessel to be followed through the underlying continued
musculature (Fig. 7D-10). Careful dissection in these tight confines will allow the operator to acquire a pedicle 2 to 3 cm long with an arterial component of 1 to 1.5 mm diameter (Fig. 7D-11). The dissection may be concluded before this point for a pedicled flap if the rotational arc is adequate.

For free tissue transplantation, the length and diameter of the pedicle limit this flap’s utility. The short pedicle length means that it must be located somewhere near the periphery of the flap to allow for reach to the recipient vessels. The risk of fat necrosis in the areas farther away from a peripheral feeding perforator is, of course, a resultant concern.

Take-Away Messages
The benefits of keeping the donor site higher up on the buttock and using the love-handle in the breast reconstruction arena are favorable considerations (see Clinical Applications cases, Figs. 7D-6 and 7D-7), but the technical limitations of this flap make it a less practical procedure than an SGAP flap, which is positioned high on the buttock. The SGAP’s pedicle length, associated increased arc of rotation, and ease of pedicle dissection, compared with the lumbar perforator flap, make it a more favorable pedicled flap for defects in its periphery as well.

References
Posterior Trunk

Bibliography With Key Annotations


Large defects after resection of skin cancers are sometimes a challenge for the reconstructive surgeon. Although skin grafts are considered as the first choice for reconstruction of large skin defects of the trunk, pedicled or free flaps sometimes provide a superior functional and aesthetic outcome. Perforator flaps represent a valuable option for these patients. The progress in understanding the perforator vessel system of the body facilitated the development of a plethora of novel pedicled flaps which could be transferred over long distances with minimal donor site morbidity. The authors presented the case of a patient with a large lumbar basalioma. The skin defect after excision was reconstructed using a novel concept based on two independent pedicled perforator flaps, a lumbar artery perforator, and a lateral intercostal artery perforator.


Despite numerous studies that have been performed recently on skin perforators and perforator flaps of various regions of the body, investigations on the back region are still insufficient. The authors investigated the anatomic characteristics and clinical applications of perforating vessels in the back region. The skin on the back region between the right and left seventh to eleventh thoracic vertebrae of 10 fresh cadavers was raised as flaps. Perforating vessels perfusing the skin with pedicle diameters of over 1 mm were included in the study. The anatomic localization, diameter, pedicle size, and the supplying vessels of these pedicles were determined. Using this information, the defects of eight patients with large meningo(myelo)celes included in the study were closed with a prepared intercostal artery perforating flap. Perforators of the back region were seen to originate from the posterior intercostal vessels. There were a higher number of perforators on the right side of the body. The most commonly observed perforators were the seventh and ninth posterior intercostal perforators, and their diameters were larger. All flaps were viable after perforator flap closure for defects in eight patients with large meningo(myelo)cele included in the clinical study. No problems were encountered in the postoperative 3-month follow-up. Because of the low donor site morbidity and wide motion capabilities, the perforator flap is a new choice of flap for the back region. Perforator pedicle flaps supplied by the posterior intercostal vessels may be safely used in congenital tissue defects, such as meningo(myelo)cele, tumors, and traumatic defects.


Autologous breast reconstruction with a perforator flap has become increasingly popular. This paper presented the free lumbar artery perforator (LAP) flap as an option for breast reconstruction. Flap harvest is easy, no muscle is sacrificed, and donor site morbidity is minimal. Anastomosis of the sensory nerve to the fourth intercostal nerve is possible. The successful use of a LAP flap for breast reconstruction is illustrated with a case report, and the surgical technique is described. This method may be a good alternative for patients with relative contraindications to breast reconstruction with a DIEP flap.


The treatment of sacral pressure sores in ambulatory patients presents a challenge to the reconstructive surgeon. The authors reported the successful use of two pedicled lumbar artery perforator flaps to cover a sacral defect measuring 12 by 25 cm. Stable coverage was provided, with protective sensibility, acceptable contour, and minimal donor site morbidity, and additional functional loss of the gluteal muscle was avoided. The configuration of the flaps resembles a butterfly.


Anatomic conditions in the lumbar region can complicate procedures for covering defects. In particular, a free flap is often required when the defect is large, in which case suitable recipient vessels must be
found to ensure revascularization. The authors described the case of a 50-year-old woman with multiple basal cell carcinomas in the lumbar radiodermatitis zone who underwent a large resection from D10 to S2. The defect was repaired using a free latissimus dorsi flap revascularized by microvascular anastomosis to the eighth intercostal pedicle. The advantages of using these recipient vessels were then considered relative to reports in the literature.


Based on a previous clinical case report in which the pedicled subcostal artery perforator flap allowed for the closure of a large defect of the lumbar region, the authors designed a study to investigate the anatomy of the subcostal artery perforator flap and to evaluate its potential for wider clinical use. A series of 14 human cadavers was studied, and 28 subcostal artery perforator flaps were dissected. The location of the perforator vessel was charted against anatomic landmarks. Measurements included the perforator caliber, pedicle length, and flap size after injection of methylene blue. The findings were compared by Doppler sonography in 15 volunteers. The subcostal artery perforator was present in all dissected specimens and in all volunteers. Its caliber measured a mean 2 mm. The location was constant at the lateral border of the latissimus dorsi muscle and between 1 and 3 cm below the lower rib end. The pedicle length reached a mean 10.5 cm when dissected up to the border of the erector spinae musculature. The vascular supply covered a mean flap size of 10 by 14 cm. The in vivo investigations confirmed the constant perforator location from the anatomic landmarks.


The intercostal vessels form an arcade between the aorta and the internal mammary vessels. Different pedicled perforator flaps can be raised on this neurovascular bundle to cover defects on the trunk. They are classified as dorsal intercostal artery perforator flap (DICAP); lateral intercostal artery perforator (LICAP); and anterior intercostal artery perforator (AICAP) flap. Between 2001 and 2004, 20 pedicled ICAP flaps were harvested in 16 patients. The indications were immediate partial breast reconstruction in 8 patients who had a quadrantectomy for breast cancer; midline back and sternal defects in 3 patients who had radical excisions for a dermatofibrosarcoma or malignant melanoma; and autologous breast augmentation (4 bilateral and 1 unilateral flap) in 5 postbariatric surgery patients. The average flap dimension was 18 by 8 cm² (range 8 by 5 cm² to 24 by 12 cm²). There were 2 DICAP flaps, 2 AICAP flaps, and 16 LICAP flaps. All but two flaps were based on one perforator. Mean harvesting time was 45 minutes for a single flap. Bilateral breast augmentation with LICAP flap necessitated longer operative time (range 2 to 3 hours), depending on whether it was combined with mastopexy. Complete flap survival was obtained. All donor sites were closed primarily.


Reconstructive microsurgery can be successfully applied to major defects of the lower back and posterior pelvis. When present, the superior and inferior gluteal vessels can be excellent free flap recipient vessels. However, if they are absent as a result of trauma or tumor ablation, a wrist carrier can be used to transfer large blocks of tissue in a staged procedure. Five patients were presented with challenging defects for which these techniques were used.


A lumbar artery island flap can be elevated based on a single lumbar artery. The authors studied the vascular anatomy using 21 specimens of lumbar arteries in 11 cadavers and investigated the skin territory of the artery using fluorescein injection. They observed lumbar perforators emerging through the lumbar fascia at the lateral border of the erector spinae muscle, situated 5 to 9 cm from the midline.
The diameter of the vascular bundle at the site of perforation ranged from 1 to 5 mm. Perforators of the second and fourth lumbar arteries were much more developed than others. The cutaneous territory supplied by the second lumbar artery extended from the posterior midline to the lateral border of the rectus sheath, and at least 10 cm above the anterosuperior iliac spine. The authors transferred four clinical flaps for coverage of ulcers on the lower back. All flaps survived and their donor site defects were closed primarily. The authors stated that the cadaver dissection, injection study, and their clinical success confirmed the feasibility of lumbar artery island flaps.


The lumbar region has been scarcely explored as a donor site for free tissue transfer or as a free flap recipient site. The lumbar integument provides a versatile prospective flap site, with a potentially well-concealed scar. Similarly, defects of this region can require recipient vessels that may be difficult to identify. Although lumbar artery perforators have been described, the reliability of perforators in this region remains questionable. The authors undertook an anatomic study combining both cadaveric and in vivo analysis of the lumbar vessels. The cadaveric component comprised both dissection and angiographic studies in fresh and embalmed cadavers (36 lumbar regions in 18 cadavers), and the clinical study comprised a CT angiographic study (44 sides in 22 patients) and an operative case report. Perforators were shown to arise from all eight lumbar arteries to enter the lumbar integument, with their size, location, and course described. Lumbar perforators were more often septocutaneous and of larger caliber. A case in which the fourth lumbar artery and concomitant vein were used as free flap recipient vessels was described, the first such reported case in the literature.


The authors reported the cumulative experience with freestyle perforator flaps from two medical centers (Hôpital Maisonneuve-Rosemont and University of Texas Southwestern Medical Center). Fifty-three pedicled perforator flaps were performed on 49 patients for local reconstruction of a range of defects at various anatomic locations: head and neck, anterior trunk, posterior trunk, perineal/gluteal, lower limb, and upper limb. Complete flap survival was obtained in 48 of 53 flaps. Complications included three cases of partial flap necrosis and two total flap failures, the latter in high-risk patients. Complete primary closure of the donor site was possible in 37 cases, especially in the trunk. Twelve patients had partial primary closure complemented by skin grafting, three cases required complete skin grafting, and one donor site required another local flap for closure. Five clinical examples were given: anterior trunk, posterior trunk, cervical region, lower limb, and upper limb.


Three-dimensional angiography was first proposed by Cornelius and advanced by Voigt in 1975. Since then, a variety of improvements have been made. Three-dimensional evaluation of perforator flaps is no longer a clinical curiosity but an absolute necessity. By combining three-dimensional digital imaging and angiography, the authors developed a new three-dimensional technique for visualizing blood vessels. This method produces a digitized model of the lumbar artery and superior gluteal artery myocutaneous perforators that enables secure elevation of the lumbar and superior gluteal artery cross-boundary perforator flap. Two cadavers were injected with whole-body lead oxide–gelatin. Spiral CT scanning and three-dimensional reconstructions were performed. Six fresh bodies were used and underwent latex injection. Specimens were then dissected by layers to document the individual perforators. An average of five superior gluteal artery myocutaneous perforators with a diameter of 0.6 mm were present in the specimens. The average diameter and area supplied by perforators from the lumbar arteries was 0.7 mm and 30 cm, respectively. The three-dimensional reconstructed model of the
lumbar region can display the modality, spatial location, and adjacent relationship of the lumbar and superior gluteal arteries. Three-dimensional modeling of lumbar and superior gluteal artery perforator flaps could provide greater insight into perforator anatomy in combination with traditional sectional imaging. Three-dimensional reconstructive modeling is now a clinically available process that in the future could provide great value in basic science investigation, clinical training, preoperative design, and virtual surgical procedures.


An anatomic study was conducted on five fresh human cadavers injected with a lead oxide–gelatin mixture as a radiopaque agent. Angiographic studies were done to map the dorsal intercostal artery perforators in detail. Each of the fourth to twelfth posterior intercostal arteries consistently supplied the dorsal perforators. Those derived from the fourth, fifth, sixth, tenth, and eleventh posterior intercostal arteries were the dominant direct cutaneous perforators. They were located within 5 cm of the spinous processes of the vertebrae and were clinically detectable by Doppler probe preoperatively. Eleven dorsal intercostal artery perforator flaps were applied in 10 cases. In 9 cases, the muscles of the latissimus dorsi, trapezius, or scapular circumflex artery had been sacrificed in previous operations. The maximum flap dimension was 31 by 13 cm. All flaps showed stable postoperative blood circulation and survived completely, except for marginal necrosis in the largest flap. No functional loss attributable to flap harvest was recognized.


Reconstruction of large-sized lumbosacral or sacral defects often is not possible using local or regional flaps, making the use of free flaps necessary. However, the difficulty of any microsurgical procedure in this region is complicated by the need to search for potential recipient vessels to revascularize the flap. The authors described the use of a free myocutaneous anterolateral thigh flap to cover a large-sized and deep lumbosacral defect. Arterial anastomosis was performed, connecting the cutaneous ALT perforator to the perforator of the second lumbar artery. In this fashion, the arterial circulation through the flap was flowing in a reverse direction through the muscle. The concomitant vein of the descending branch of the lateral circumflex femoral artery was hooked up to the thoracodorsal vein using a long interposition vein graft, because the perforator of the second lumbar vein was too small. Postoperative healing was uneventful. A successful reconstruction of a lumbar defect has shown that local perforators in the lumbar area may be accessible for easier perforator-to-perforator anastomoses and that the muscular part of the myocutaneous ALT flap can survive on retrograde arterial perfusion from a perforator of the skin island.


Perforator flaps based on the integument of the trunk have been well described in the literature; however, the anatomy of many donor sites has yet to be adequately documented. The integument of the lateral lumbar region of the trunk is supplied by a number of source arteries (lower posterior intercostal, lumbar, superior epigastric, deep inferior epigastric, superficial inferior epigastric, superficial circumflex iliac, deep circumflex iliac) whose large perforators may be suitable for perforator flap harvest. The purpose of the study was to describe the vascular anatomy of these perforators in the lateral lumbar region. A series of five fresh human cadavers were studied using a lead oxide–gelatin injection technique. The integument of the trunk (10 sides or hemitrunk specimens) was dissected, and the perforating vessels (diameter 0.5 mm or larger) were identified, noting vascular origin, diameter, and pedicle length. Radiographs of tissue specimens were digitally analyzed using Scion Image for Windows software to
determine vascular territories. The source vessels contributed a summed mean of 33 perforators per hemitrunk, with a mean emerging vessel diameter of $0.7 \pm 0.2$ mm and a corresponding mean superficial pedicle length of $31 \pm 24$ mm. The total area of skin supplied directly by these 33 perforators was $1200 \text{ cm}^2$, equating to a mean area of $37 \text{ cm}^2$ per perforator.


Large lumbo sacral defects remain a difficult challenge in reconstructive surgery, especially in nonparaplegic patients. Traditional options for closure include local rotation or transposition flaps and myocutaneous flaps. However, these flaps are not an optimal option in previously irradiated or operated areas, or in cases of large defects. Application of the perforator principle to the traditional myocutaneous flap creates perforator flaps, which are an additional tool in the treatment of these defects in the nonparaplegic patient. A large amount of healthy, well-vascularized tissue can be transferred on one perforator without sacrificing important underlying muscles. The arc of rotation is also larger than in traditional flaps.

The authors presented an anatomic overview of three types of pedicled perforator flaps: the superior gluteal artery perforator flap, the lumbar artery perforator flap, and the intercostal artery perforator flap. They also reported four patients in whom a pedicled perforator flap was used to reconstruct a large lumbo sacral defect.


An angiosome is a composite block of tissue that is supplied anatomically by source (segmental or distributing) vessels that span between the skin and bone. In addition to supplying the deep tissues, the source vessels of these angiosomes supply branches to the overlying skin, which pass either between the deep tissues or through the deep tissues, usually muscle, to pierce the outer layer of the deep fascia, usually at fixed skin sites. Hence perforator flaps, when dissected to the underlying source vessels, involve tracing vessels either between the deep tissues, whether muscle tendon or bone, or through the deep tissues, usually muscle.


The blood supply to the skin and underlying tissues was investigated by ink injection studies, dissection, perforator mapping and radiographic analysis of fresh cadavers and isolated limbs. The results were correlated with previous regional studies done in this department. The blood supply is shown to be a continuous three-dimensional network of vessels not only in the skin but also in all tissue layers. The anatomic territory of a source artery in the skin and deep tissues was found to correspond in most cases, giving rise to the angiosome concept. Arteries follow closely the connective tissue framework of the body. The primary supply to the skin is by direct cutaneous arteries which vary in calibre, length and density in different regions. This primary supply is reinforced by numerous small indirect vessels, which are “spent” terminal branches of arteries supplying the deep tissues. An average of 374 major perforators was plotted in each subject, revealing that there are still many more potential skin flaps. An arterial roadmap of the body provides the basis for the logical planning of incisions and flaps. The angiosomes define the tissues available for composite transfer.


The author presented a cadaveric study of 44 fourth lumbar arteries, veins, and nerves. Dye injected to the area of perfusion included profusion to the posterior iliac bone. At the lateral margin of the sacrospinal muscle, the diameter of the artery was 0.8 to 1.8 mm; the accompanying vein was 0.8 to 2.4 mm, with two veins present in 42 of 44 specimens.
## ANATOMIC LANDMARKS

| **Landmarks** | A large, flat, triangular muscle located in the superior aspect of the back. Its wide area of attachments includes the base of the skull, lateral shoulder, and thoracic vertebral column. Superiorly, it is superficial to the levator scapula; inferiorly, it extends over the superior edge of the latissimus dorsi muscle. |
| **Size** | Muscle: 34 × 18 cm; skin: 10 × 22 cm with primary closure. |
| **Origin** | External occipital protuberance, the medial third of the superior nuchal line of the occipital bone, ligamentum nuchae, and spinous processes of C7 through T12. |
| **Insertion** | Superior fibers, lateral third clavicle; middle fibers, spine of scapula; inferior fibers, acromion. |
| **Function** | Rotates the scapula and elevates the shoulder during full arm abduction and flexion. |
| **Composition** | Muscle, myocutaneous, or cutaneous. |
| **Flap Type** | Type II. |
| **Dominant Pedicle** | Transverse cervical artery. |
| **Minor Pedicles** | Occipital artery, dorsal scapular artery, posterior intercostal arteries. |
| **Nerve Supply** | Motor: Spinal accessory nerve (eleventh cranial nerve). Sensory: Sensory branches from the third and fourth cervical nerves and posterior cutaneous branches of the intercostal nerve. |
Section 7E

POSTERIOR TRUNK

Trapezius Flap

CLINICAL APPLICATIONS

Regional Use
- Scalp
- Head and neck
- Oral cavity
- Posterior trunk
- Shoulder
- Anterior trunk

Specialized Use
- Midline back wounds
Intercostal perforator nerves

ANATOMY OF THE TRAPEZIUS FLAP

Dominant pedicle: Transverse cervical artery
Minor pedicles: Dorsal scapular artery; perforating intercostal arteries
ANATOMY

**Landmarks**
This large, flat, triangular muscle is located in the superior aspect of the back. Its wide area of attachments include base of skull, lateral shoulder, and inferior thoracic spine.

**Composition**
Muscle, myocutaneous, or cutaneous.

**Size**
Muscle: 34 × 18 cm; skin: 10 × 22 cm with primary closure.

**Origin**
External occipital protuberance, the medial third of the superior nuchal line of the occipital bone, ligamentum nuchae, and spinous processes of C7 through T12.

**Insertion**
Superior fibers, lateral third clavicle; middle fibers, spine of scapula; inferior fibers, acromion.

**Function**
Rotates the scapula; elevates the shoulder during full arm abduction and flexion.

**Arterial Anatomy (Type II)**

**Dominant Pedicle**  
*Transverse cervical artery*

**Regional Source** Thyrocervical trunk 80%; subclavian artery 20%.
**Length** 4 cm.
**Diameter** 1.8 mm.
**Location** Posterior inferior neck and superior anterior margin of the muscle.

**Minor Pedicle**  
*Dorsal scapular artery (deep branch of transverse cervical artery)*

**Regional Source** Transverse cervical artery or subclavian artery.
**Length** 4 cm.
**Diameter** 1.6 mm.
**Location** Perforates the rhomboid muscles and enters the distal portion of the trapezius muscle.

**Minor Pedicle**  
*Branch of occipital artery*

**Regional Source** External carotid artery.
**Length** 3 cm.
**Diameter** 1 mm.
**Location** Adjacent to the muscle origin at the external occipital protuberance.

**Minor Pedicle**  
*Posterior intercostal arteries*

**Regional Source** Descending aorta.
**Length** 1 to 2 cm.
**Diameter** 0.5 mm.
**Location** Vascular pedicles enter the muscle along the posterior midline adjacent to the cervical and thoracic vertebral bodies.

**Venous Anatomy**
The transverse cervical artery is accompanied by a transverse cervical vein whose diameter at its base is 2 mm. The dorsal scapular artery is accompanied by dorsal scapular vein with a diameter of 2 mm at its origin. Branches of both the occipital artery and the intercostal arteries are accompanied by venae comitantes.

**Nerve Supply**

**Motor**
Spinal accessory nerve (eleventh cranial nerve).

**Sensory**
Sensory branches from the third and fourth cervical nerves and posterior cutaneous branches of the intercostal nerves.
**Vascular Anatomy of the Trapezius Flap**

Fig. 7E-2

**Dominant pedicle:** Transverse cervical artery with descending branch (D)

$m_d$, Dorsal scapular artery
Fig. 7E-2

Dominant pedicle: Transverse cervical artery (D)
Minor pedicles: Branch of occipital artery (m1); branches of posterior intercostal arteries (m2); dorsal scapular artery (m3)
FLAP HARVEST
Design and Markings
A line drawn from T12 to the acromion will outline the location of the trapezius muscle for a muscle-only flap. A vertical incision can be made directly over the muscle to allow its release and rotation to accomplish the reconstructive goal. For midline back wounds, access can often be gained from the wound itself by elevating the overlying skin and subcutaneous tissues.
Patient Positioning
For back and posterior scalp applications, a prone position is preferred to facilitate dissection and flap inset. For reconstruction of the head and neck and anterior chest, a lateral decubitus position is preferred to allow both harvest and inset in the same position.

Fig. 7E-4
GUIDE TO FLAP DISSECTION
The skin incision is made directly down to the overlying muscle, then wide elevation of
the skin and subcutaneous tissues off the muscle is performed. In the most common ap-
plication, for midline upper back wounds, the lateral border of the muscle is identified and
undermined. The origin of the muscle is released from the spinous processes from caudal
to cephalad. Once the vascular pedicle is visualized superiorly, the muscle can be divided
lateral to the pedicle, which allows rotation of the muscle in an open book fashion to cover
midline wounds. Care is taken to preserve the superior fibers of the trapezius as much as
possible to maintain shoulder function. For applications that include head and neck recon-
struction or when a long vascular pedicle is required, dissection proceeds to the origin of
the transverse cervical vessel with division of intercostal vessels. Once the vascular pedicle
is identified, the muscular attachments to the neck and occiput can be divided to create an
island flap that can then be passed through the neck to the face for reconstruction.
FLAP VARIANTS

- Myocutaneous flap
- Dorsal scapular artery perforator flap
- Extended lateral flap
- Osseous flap

Myocutaneous Flap

Similar to other flaps of the back, a 9 to 10 cm wide flap can be designed with primary closure of the donor site. If the skin paddle of the flap is designed over the territory of the trapezius muscle, it will be well perfused. Most commonly used flaps are designed with a vertical orientation, which extends the reach of the flap to the occiput and can be useful for head and neck reconstruction when skin is required.

The surgeon should be careful not to go beyond the location of the muscle, because the distal muscle and skin are supplied mainly by the dorsal scapular system, which is not routinely included with the flap. Once the skin paddle has been planned, dissection begins with incision of the skin paddle around its circumference and freeing of the skin and subcutaneous tissues off the entire surface of the trapezius elsewhere. Inferiorly and laterally, the edge of the muscle is identified and the muscle elevated, dividing its origin from the spinous processes from caudad to cephalad. Dissection at this point proceeds similar to that described earlier. If an extended skin paddle is required inferiorly, one must take care to preserve the dorsal scapular perforator, which can be found on the deep surface of the muscle piercing the rhomboid muscle. Incorporation of this vessel, which normally is supplied by the transverse cervical artery as a deep branch, requires division of the rhomboid muscle. A second option to capture this territory would be to perform a formal delay procedure on a distal portion of the flap.
Dorsal Scapular Artery Perforator Flap
The dorsal scapular artery (DSA) perforator flap is based on the dorsal scapular artery, which is the deep branch of the transverse cervical artery. It runs posteriorly in the neck through the brachial plexus and then under the trapezius and levator scapular muscles to run directly on the rib cage. At the medial angle of the scapula, the DSA gives off a superficial branch that is the basis of the perforator flap. This branch pierces the rhomboid muscle and enters the deep surface of the trapezius muscle, which it supplies. It then gives off cutaneous perforators that supply the overlying skin paddle. This perforator can be located by Doppler examination and usually enters the muscle within 2 cm of its lateral edge within the middle third of the muscle vertically. Flaps as large as 20 by 20 cm have been harvested on this perforator, but skin grafting would be required for donor site closure. Once the flap is designed and its skin margins incised, dissection proceeds along the lateral border of the trapezius muscle superficial to the deep fascia. Once the cutaneous perforator is identified, it is followed deeply through the trapezius muscle. Once through the trapezius muscle, the emergence of the vessel from the rhomboid is identified. Dissection then proceeds through the rhomboid muscle where the deep branch of the DSA is identified. It is ligated distally to allow further proximal dissection. All muscular branches to the levator scapula and omohyoid are also ligated. Dissection of the vessels proceeds superiorly until adequate pedicle length is available. The flap is used as a pedicle flap, but its use as a free tissue transfer is possible.

Fig. 7E-6  A, Emergence of the lower trapezius cutaneous perforator.  B, Dorsal scapular perforator island flap. The trapezius muscle is split, and the rhomboid major is divided.
Extended Lateral Flap

The extended lateral flap is based on the ascending branch of the transverse cervical artery. The flap is located over the lateral arm between the acromial clavicular joint and the lower lateral third of the upper arm. Myocutaneous and direct fasciocutaneous pedicles at the level of the acromial clavicular joint are not visualized during elevation of this flap. After detachment of the trapezius fibers, which insert to the clavicle, one may visualize the ascending branch of the transverse cervical artery, but this is not required for elevation. After the flap is designed, the incision is made around the skin island and the muscular fibers of insertion into the joint are incised. The muscle is then elevated from lateral to medial, with visualization of the deep surface of the trapezius muscle. From this viewpoint the ascending branch of the transverse cervical artery and veins are visualized and can be preserved. Muscular fibers originating from the spine of the scapula are divided. The trapezius muscle is divided at its junction of the upper and middle third of the muscle. The degree of the division of the muscle is dictated by the reconstructive need. Because there are many other less morbid flap choices with more acceptable donor sites, this variant of the flap is rarely if ever used (see Section 6F, Supraclavicular Artery Flap).

Osseous Flap

An osseous component to the flap has been described for both the trapezius muscular flap and the DSA perforator flap. The muscular flap uses its origin from the scapular spine, whereas the dorsal artery perforator flap uses a branch of the DSA to the medial border and tip of the scapula. Although isolated cases have been described, routine use of such flaps is not recommended, because other more reliable and less morbid flaps exist.
ARC OF ROTATION

Muscle Flap

With the rotation point at the posterior base of the neck, the muscle will reach the posterior skull, cervical and thoracic vertebral column, midface, and neck. Further lengthening is possible by division of the superior muscle fibers, which allows the flap to reach the upper third of the face.

![Diagram showing the arc of rotation for a vertical standard flap](image)

Arc to vertebral column, posterior neck, and occipital skull

Arc to face and anterior neck

Fig. 7E-7
Myocutaneous Flap
A vertically oriented skin design overlying the trapezius muscle will have a similar arc of rotation of the muscle. Extension of the flap can be gained by a delay procedure or inclusion of the dorsal scapular vessels, as described.

Dorsal Scapular Artery Perforator Flap
Significant length can be obtained on the dorsal scapular perforator flap as an island flap. When passed anteriorly through a clavicular incision, the flap can reach the anterior chest, axilla, and lower face.

Fig. 7E-8
Arc of rotation with its long leash
Extended Lateral Flap
With its rotation point at the acromial clavicular joint, this flap will reach the middle and inferior thirds of the face, ear, and oral cavity.

Fig. 7E-9

FLAP TRANSFER
Muscle Flap
For posterior midline defects, simple transposition of the muscle or an open-book movement can be performed for reconstruction. For use in the anterior neck or head and neck, the flap must be passed through a subcutaneous tunnel. The pedicle must not be compromised with an inadequate tunnel.
Posterior Trunk

Trapezius

For most defects of the back and posterior scalp, simple transposition of the flap is performed, with care taken not to kink or compress the vascular pedicle. For use anteriorly in the head and neck, the subcutaneous tunnel must be adequately sized to allow passage of the bulk of the flap without compromising its integrity.

Dorsal Scapular Artery Perforator Flap

For posterior defects, simple transposition can be performed. For use anteriorly, the flap is tunneled, with care taken not to put excessive tension on the vessels, which have been freed from any muscular support and are more prone to shear injury.

Extended Lateral Flaps

These flaps are transferred by local advancement or transposition. For some uses in the head and neck, a two-stage approach may be used whereby initial attachment to the head and neck is performed first, and division and inset is completed as a second stage.

Myocutaneous Flap

For most defects of the back and posterior scalp, simple transposition of the flap is performed, with care taken not to kink or compress the vascular pedicle. For use anteriorly in the head and neck, the subcutaneous tunnel must be adequately sized to allow passage of the bulk of the flap without compromising its integrity.

Dorsal Scapular Artery Perforator Flap

For posterior defects, simple transposition can be performed. For use anteriorly, the flap is tunneled, with care taken not to put excessive tension on the vessels, which have been freed from any muscular support and are more prone to shear injury.

Extended Lateral Flaps

These flaps are transferred by local advancement or transposition. For some uses in the head and neck, a two-stage approach may be used whereby initial attachment to the head and neck is performed first, and division and inset is completed as a second stage.

FLAP INSET

All Variants

The flap must be supported deeply and tension minimized on the vascular pedicles. In cases in which muscle is included with the flap and the flap is passed through a subcutaneous tunnel, one should prepare for postoperative swelling of the muscle and ensure that the tunnel is adequately sized to accommodate this.

DONOR SITE CLOSURE

Muscle Flap

The large dead space created should be adequately drained. Skin closure can be performed without tension, because no skin has been removed.

Myocutaneous Flap and Dorsal Scapular Artery Perforator Flap

Mobilization of the surrounding subcutaneous tissues should allow primary closure of the back in flaps 10 cm or less, depending on the patient and the degree of skin laxity. Larger flaps have been taken that also have allowed primary closure. When primary closure is not obtainable, skin grafting can be performed.

Extended Lateral Flap

One downside to use of this flap is the need for skin grafting for the donor site. When a two-stage reconstruction is planned, a portion of the flap may be returned to the donor site to remove some of this skin-grafted area. The final cosmesis of this donor site is poor compared with that of other available reconstructive flaps.
CLINICAL APPLICATIONS
This 70-year-old man had undergone resection of a sarcoma of the postauricular scalp and postoperative irradiation. He presented after a failed skin graft and exposure of the dura in the wound. A trapezius myocutaneous flap was used to reconstruct the area.

Fig. 7E-10  A, Preoperative appearance of the wound with some residual skin graft. B, The defect after resection with no evidence of cancer recurrence. C, Design of the vertically oriented myocutaneous flap. Note that the skin design completely overlies the muscle for best vascularity. D, After flap elevation. Only a vertical strip of muscle that contains the transverse cervical branches is included with the flap. The dorsal scapular perforator was divided. E, Closeup of the feeding transverse cervical pedicle at the base of the neck. This was the limit of flap mobilization in this case.
Fig. 7E-10  F, Flap transposed through a generous subcutaneous tunnel. G, Flap inset without tension. Primary closure of the back was obtained. H, The patient is seen at 1-month follow-up. (Case supplied by MRZ.)
This 56-year-old woman smoker had a chronic neck wound after cervical spine surgery and exposure of her hardware. The wound persisted even after removal of the hardware.

**Fig. 7E-11**  
A, Site of chronic wound and sinus and markings for the trapezius muscle.  
B, Defect after aggressive debridement and elevation of a vertical strip of muscle that includes the transverse cervical vascular pedicle and spares the superior fibers of the trapezius muscle.  
C, Muscle transposed through a subcutaneous tunnel.  
D, After primary closure of both donor and recipient sites. The patient healed uneventfully. (Case supplied by MRZ.)
This 60-year-old man had recurrent squamous cell carcinoma of the scalp, multiple surgical excisions, and a history of scalp irradiation.

Fig. 7E-12  A, Preoperative view of his latest cancer recurrence with exposed irradiated scalp. The dotted line denotes the proposed wide excision of the tumor. The patient's medical comorbidities precluded treatment with free tissue transfer. B, Design of the extended trapezius flap to reach the scalp defect. C, Flap elevated with inclusion of the dorsal scapular artery perforator to maximize blood supply of the distal flap. D, Demonstration of arc of rotation. E, Flap inset after passing it through a generous subcutaneous tunnel. The donor site was closed primarily. (Case supplied by MRZ.)
This 63-year-old woman with an unclassified sarcoma of the cervical spine had been treated by resection, dural reconstruction, and spinal stabilization with hardware. The spinal cord and hardware were covered with a right trapezius muscle flap to minimize the risk of hardware exposure, infection, and CSF leak. The transverse cervical pedicle was not visualized or dissected in this case, but the arc of rotation of the muscle easily reached the nuchal line of the head superiorly.

Fig. 7E-13  A, The inferior portion of the right trapezius muscle was released from its origins from the thoracic spinous processes and elevated out of its bed as the most superficial muscle of the back. B, The muscle flap was transposed after vertical division of the muscle (yellow arrow) lateral to the transverse cervical vessels. C, The muscle flap was then transposed nearly 180 degrees clockwise and used to cover the dural reconstruction and hardware and to fill the dead space following tumor resection. (Case courtesy David W. Chang, MD.)
This 45-year-old man underwent resection of a recurrent synovial sarcoma of his cervical spine. Bilateral trapezius muscle flaps were used to cover the dural repair and to cover and wrap the hardware to minimize the risk of CSF leak, hardware exposure, and infection. The cervical portion of both trapezius muscles had been previously irradiated and partially resected at the current and previous operations.

**Fig. 7E-14**  
A, The resection defect was reconstructed with a dural substitute patch, hardware for spinal stabilization, and allograft bone chips. B, The lower half of the bilateral trapezius muscles were divided from their origins from the thoracic spinal processes and elevated in an inferior to superior direction. C, The transverse cervical pedicles were not dissected, and the muscles were divided vertically (yellow arrows) lateral to their pedicles. The arc of rotation easily allowed the muscle flaps to reach any upper back or neck midline wounds up to the nuchal line superiorly. D, The muscle flaps were inset over the dural patch and around the spinal rods and screws. E, The result is seen 3 months postoperatively. (Case courtesy David W. Chang, MD.)
A defect resulted from resection of a Ewing’s sarcoma in this 18-year-old girl.

Fig. 7E-15  A and B, A trapezius myocutaneous flap was elevated, preserving the upper trapezius muscle. C, The flap was brought to the back of the neck through a subcutaneous tunnel. The donor site was closed primarily. D, Both the donor and recipient sites healed well, with no functional deficit. (Case courtesy David W. Chang, MD.)
This 68-year-old man presented with a third recurrence of a spindle cell sarcoma in the cervical spine with cord compression after multiple previous resections, free flap reconstruction, and radiation therapy. Radical resection with stabilization of the spine with hardware was performed.

Fig. 7E-16  A and B, A pedicled trapezius myocutaneous flap was elevated, preserving the upper trapezius muscle. C and D, The flap was rotated to cover the exposed spinal cord and hardware. E, A well-healed flap at 3-month follow-up. (Case courtesy David W. Chang, MD.)
Pearls and Pitfalls

- The trapezius is a functional muscle, and its use in reconstruction can cause functional disability, including shoulder weakness and shoulder droop. Preservation of the superior fibers of the trapezius can help to minimize this morbidity. Using the DSA perforator flap leaves all muscle intact and functional.
- Caution should be exercised in patients who have undergone previous neck surgery, including radical neck dissection, because the transverse cervical artery may have been ligated. In such cases, a preoperative arteriogram may be warranted, or a different donor site can be used.
- Skin paddles are reliably carried in a superior two thirds of the muscle distribution; inferior third perfusion is less reliable, and if critical for the reconstruction, inclusion of the dorsal scapular vessel should be considered or the procedure should involve a preliminary delay procedure.
- Postoperative shoulder immobilization can be helpful in reducing tension in the donor site.
- Because of the cosmetic deformity created at the donor site, the extended lateral flap should be considered only when all other standard options are not possible.
- Although bone may be carried with different variants of the trapezius flap, other more acceptable donor sites are available that produce much less morbidity to shoulder function, and these should be considered first.
- For use on the face, the trapezius flap has a poor color match and has thick dermis, which may be less desirable for facial skin reconstruction.

EXPERT COMMENTARY
Pierre M. Chevray, Peirong Yu, David W. Chang

Indications
The trapezius muscle or myocutaneous flap may be useful in the reconstruction of defects of the upper midback, the base of the neck, head and neck, and the shoulders. The flap is generally used as a pedicled flap, based on its dominant blood supply, the transverse cervical artery and vein. The muscle measures about 32 by 18 cm², and the skin island supplied by myocutaneous perforators may extend up to 10 cm beyond the inferior edge of the muscle as long as at least one third of the skin overlies the trapezius muscle. If primary donor site closure is desired, the width of the skin island generally should be less than 10 cm. However, a wider skin island may be harvested while still allowing primary closure if a bilobed flap design is selected (Fig. 7E-17).

Recommendations

Technique
With this design, the transverse extension of the bilobed flap assists in a V-Y closure of the defect created by the larger, vertical component of the flap. To avoid disruption of the donor site closure, anterior rotation or abduction of the shoulder should be minimized for 4 to 6 weeks postoperatively. The donor site morbidity with the trapezius flap is minimal if the superior 4 cm of the muscle, the acromial attachment, and the spinal accessory nerve are preserved.
The trapezius muscle is the most superficial muscle of the back, which makes elevation of a trapezius muscle flap straightforward. The skin paddle of the trapezius myocutaneous flap should be positioned largely over the muscle, which makes design and elevation of a trapezius myocutaneous flap straightforward.

In most cases, the trapezius flap will be elevated as a vertical strip of muscle with or without an overlying skin paddle for reconstruction of the occiput, posterior neck, and/or the upper back. The critical step is to identify the location of the transverse cervical pedicle vessels and divide the trapezius muscle lateral to the pedicle in a vertical direction to create a strip of muscle which includes the pedicle vessels. The superior half of the muscle is usually spared to prevent a shoulder drop and surface anatomy deformity. Therefore the transverse cervical pedicle vessels are typically visualized and identified, but usually not dissected unless extra flap length is required.

The standard trapezius muscle flap will reach the posterior neck up to the nuchal line. Additional division of the superior portion of the muscle and dissection of the transverse cervical pedicle allows the arc of rotation of the flap to be extended, at the cost of potential shoulder drop and shoulder deformity. Use of an extended skin paddle can allow defects of the upper scalp to be reached, as shown in Fig. 7E-12.

**Take-Away Messages**

A routine trapezius flap is straightforward to perform, but the extended flap is more difficult to dissect, since it has to include the dorsal scapular artery. An extended flap may be needed to reach the oral cavity or higher; the dorsal scapular artery becomes the limiting factor for pedicle length and needs to be divided, making this flap less reliable. Because of the widespread use of free flaps for head and neck reconstruction, the trapezius flap is now rarely used for that purpose. However, it is still a useful flap to cover defects in the upper midback, base of the neck, and shoulders.
Bibliography With Key Annotations


This study presented an effective repair method for the hemimandibular and oral defects produced during the ablation of advanced oral malignant tumors. Nine patients (five males and four females ranging in age from 18 to 74 years; mean age 51.3 years) with advanced oral malignant tumors were treated. Trapezius osteomyocutaneous island flaps, including the acromion, spine, and part of the medial scapular border were used to repair the hemimandibular and oral defects. No major flap failure occurred. Donor site problems were minimal, with limited shoulder motion in all patients. The functional results in terms of speech, swallowing, and facial contour were satisfactory. The patients were followed for 6 to 24 months (average 15.2 months): six of them are alive with no disease, two alive with disease; and one died of a lung metastasis.


This study explored an effective method for repairing cranio-axillofacial soft tissue defects after radical craniofacial surgery in four patients with malignant tumors involving the skull base and frontal region. The large cranioaxillofacial soft tissue defects were reconstructed using an extended vertical lower trapezius island myocutaneous flap based on the transverse cervical artery. The flaps were 8 to 12 cm long and 5 to 7 cm wide. No major flap failure occurred, and there was no shoulder dysfunction. The patients were followed for 3 to 12 months. One patient had a local recurrence, and another died of lung metastasis 12 months postoperatively. The extended vertical lower trapezius island myocutaneous flap is a large, simple, reliable flap. It is preferred for reconstructing cranioaxillofacial soft tissue defects when a pedicled flap is used following craniofacial surgery for cancer.


This study explored an effective repair method for oral and maxillofacial soft tissue defects after salvage surgery for patients with recurrent oral carcinoma. The study included eight patients (six women and two men; mean age 56.9 years); four with recurrent oral squamous cell carcinoma of the tongue; two with cancer of the oral cavity floor, and two with buccal carcinoma. The patients were treated with salvage surgery, and the oral and maxillofacial soft tissue defects were reconstructed primarily by extended vertical lower trapezius island myocutaneous flap. No flap failure occurred. The donor sites were closed primarily. There were no disabilities with regard to shoulder motion. The patients’ survival period was 6 to 30 months (average 13.1 months). There was one recurrent case.


The authors explored an effective method to repair defects in the tongue that had been produced during removal of advanced tongue cancers. Eighteen patients with advanced squamous cell carcinoma of the tongue were treated. Extended vertical lower trapezius island myocutaneous flaps based on the transverse cervical artery were used to repair more than half the tongue. No flap failed completely,
and no shoulder movement was affected. The lingual contours were excellent. The functional results in terms of speech and swallowing were satisfactory. The patients were followed for 6 to 24 months. Three of them were alive with disease and two had died of local recurrence or metastasis at 18 and 20 months, respectively. The extended vertical lower trapezius island myocutaneous flap is a large, simple, and reliable flap that is preferred for reconstruction of defects of the tongue after removal of advanced tongue cancer.


The authors described the extended vertical lower trapezius island myocutaneous flap for reconstructing large defects of the neck. Eleven patients with neck recurrence of oral carcinoma were treated using salvage surgery and an extended vertical lower trapezius island myocutaneous flap based on the transverse cervical artery was used to repair the large defect in the neck. No major flap failure occurred. No disabilities were observed in terms of shoulder motion. The patients were followed for 6 to 22 months.

Four patients developed local recurrence: two of them were still alive with the disease and two had died.


Upper thoracic wounds with exposed hardware from spinal instrumentation and previous radiation present a subset of back wound coverage problems that lend themselves to a unique opportunity to use the distal trapezius myocutaneous flap. The unirradiated, healthy skin paddle can be transposed between the irradiated skin edges to seal and cover the exposed hardware and achieve early primary healing of the back wound without the need for a skin graft. The authors reviewed their series of upper back radiated wounds reconstructed with the trapezius myocutaneous flaps, immediately at the time of the spinal surgery and secondarily after the incisional wound breakdown, to cover the exposed hardware. Their contiguous skin flap design strategy, results, and complications were discussed.


Reoperation for malignant disease of the cervicothoracic spine can lead to compromised wound healing as a result of poor tissue quality from previous operations, heavily irradiated beds, and concomitant steroid therapy. Other complicating factors include exposed dura and spinal implants. Introducing well-vascularized soft tissue to obliterate dead space is critical to reliable wound healing. The authors conducted a retrospective review of all patients undergoing trapezius muscle turnover flaps for closure of complex cervicothoracic wounds after spinal operations for metastatic or primary tumors. Six patients (three men and three women) were operated over an 18-month period (mean age 43 years). Primary pathologies included radiation-induced peripheral nerve sheath tumor (two), chondrosarcoma (one), non-small-cell lung cancer (one), paraganglioma (one), and spindle cell sarcoma (one). Trapezius muscle turnover flaps were unilateral and based on the transverse cervical artery in every patient. Indications for flap closure included inability to perform primary layered closure, an open wound with infection, and exposed hardware. All patients had previous operations of the cervicothoracic spine (mean 5.8 months; range 2 to 9 months) for malignant disease and prior radiation therapy. Exposed dura was present in all patients, and two had dural repairs with bovine pericardial patches. Spinal stabilization hardware was present in four patients. All patients underwent perioperative treatment with systemic corticosteroids. All flaps survived, and primary wound healing was achieved in each patient. The only wound complication was a malignant pleural effusion communicating with the back wound, which was controlled with a closed suction drain. All wounds remained healed during the follow-up period. Four patients died from progression of disease within 10 months of surgery. The trapezius turnover flap has been used successfully when local tissue conditions prevent primary closure, or in the setting of open, infected wounds with exposed dura and hardware. The ease of flap elevation and minimal donor site morbidity make it a useful, single-stage reconstructive option in these difficult wounds.

The authors retrospectively studied the results of 22 patients treated for postoperative soft tissue defects of the spine. In the literature, the treatment of postoperative spine infections is with serial debridement, antibiotic irrigation catheters, drains, and occasional removal of spinal implants. Muscle flaps have received scant mention in the surgical literature for spine coverage. The 15 patients in the authors’ group 1 had postoperative wound infections or dehiscences. Group 2 (seven patients) had “prophylactic” flaps at the time of their initial spine surgery. The indications for “prophylactic” closure included multiple prior surgeries, prior infection, and previous radiation therapy. Group 1 was treated with drainage, dressing changes, and one-stage flap closure of their wounds. Sliding paraspinal muscle flaps were the flaps of choice. Group 2 was treated with a variety of closure techniques at the time of their initial surgery. The average defect size was 10 vertebral bodies long. Despite the large defect size, 19 of 20 surviving patients currently have healed wounds, and all patients have maintained their instrumentation. Two patients died of causes unrelated to their wound problems. A group 1 patient with complete loss of a superior gluteal artery flap was salvaged with a contralateral gluteus muscle flap. Another group 1 patient had intermittent drainage from under a trapezius flap, which covered a cervical spine fusion. Four patients had minor wound complications. Flaps are a useful adjunct in the treatment of patients with complex spine wounds. Sliding paraspinal muscle flaps can effectively close wounds from the high cervical to the low lumbar area in one operative procedure. These patients can go on to successful spine fusion.


A review of the literature showed that there is no uniform nomenclature for the branches of the subclavian artery and the vessels supplying the trapezius muscle and that the different opinions on the vessels supplying the pedicled lower trapezius myocutaneous flap lead to confusion and technical problems when this flap is harvested. The authors attempted to clarify the anatomic nomenclature; they also described exactly how the flap is planned and harvested and discussed the clinical relevance of this flap as an island or free flap. They dissected both sides of the neck in 124 cadavers to examine the variations of the subclavian artery and its branches, the vessel diameter at different levels, the course of the pedicle, the arc of rotation, and the variation of the segmental intercostal branches to the lower part of the trapezius muscle. Clinically, the flap was used in five cases as an island skin and island muscle flap and once as a free flap. The anatomical findings and clinical applications proved that there is a constant and dependable blood supply through the dorsal scapular artery (synonym for the deep branch of the transverse cervical artery in the case of a common trunk with the superficial cervical artery) as the main vessel. Harvesting an island flap or a free flap is technically demanding but possible. Planning the skin island far distally permitted a very long pedicle and wide arc of rotation. The lower part of the trapezius muscle alone could be classified as a type V muscle according to Mathes and Nahai because of its potential use as a turnover flap supplied by segmental intercostal perforators. The lower trapezius flap is a thin and pliable myocutaneous flap with a very long constant pedicle and minor donor site morbidity, permitting safe flap elevation and the possibility of free tissue transfer.


Elevation of the skin along with its deep fascia vascular network is a recent addition to flap design. The longitudinal trapezius fasciocutaneous flap was first introduced in 1996; at that time it did not receive much attention, although it has many significant benefits compared with other available procedures. Sixteen trapezius fasciocutaneous flaps were elevated in 15 patients for reconstruction of severe scarring of the neck and midface. All flaps were based on the deep branch of the transverse cervical artery and included the overlying fascia of the trapezius muscle. Delaying was applied for very long flaps.
Two flaps developed minimal distal necrosis (less than 5 cm) because of longer pedicles (more than 10 cm below the muscle border). The results indicate that an extra-long back fascia flap based on the descending branch of the transverse cervical artery could be formed, which would be long enough to reconstruct the entire neck and safely transfer it to the midface. The vertical trapezius fasciocutaneous flap, with its abundant tissue, excellent blood supply, anatomic proximity, wide arc of rotation, and hidden donor site scar, provides a simple and reliable method for primary reconstruction of various midface and neck defects.

Halvorson EG, Avram R, Disa JJ. The lower trapezius “reverse-turnover” flap. Plast Reconstr Surg 122:45e-46e, 2008. Since its introduction, the reverse-turnover latissimus dorsi flap has been established as a reliable muscle flap for coverage of lower midspinal wounds. Based on its reversed secondary segmental blood supply, a medially based flap can be turned over for coverage of midline posterior trunk defects. This same concept is used when turnover pectoralis major muscle flap surgery is performed. It is now recognized that the lower trapezius muscle has a dominant dorsal scapular pedicle and secondary segment pedicles arising from the intercostal system. This article presents a novel use of the lower trapezius muscle as a reverse-turnover flap, based on secondary segmental posterior intercostal artery perforators, for coverage of a midline midthoracic wound.

Ihara K, Shigetomi M, Muramatsu K, et al. Pedicle or free musculocutaneous flaps for shoulder defects after oncological resection. Ann Plast Surg 50:361-366, 2003. Management of soft tissue defects of the shoulder was described. Extensive defects of soft tissues with or without overlying skin were created after resection of sarcomas in five patients. Reconstruction was performed using myocutaneous flaps, which included three pedicle latissimus dorsi and two free tensor fascia lata flaps. Simultaneous functioning replacement of the defects of the trapezius and deltoid muscles were each achieved in two patients. Primary wound healing was achieved, and each patient recovered good contour of the shoulder. Functional results were satisfactory in all patients with an average score of 93.4% using the system of the Musculoskeletal Tumor Society. The four functioning muscles recovered active contraction in the transferred position. The shoulder elevation was normal in three patients, and was 90 degrees and 30 degrees in one patient each. All patients remained disease free at the time of latest follow-up. Thus shoulder defects of the soft tissues can be managed appropriately with the two representative myocutaneous flaps.

Kneser U, Beier JP, Dragu A, et al. Transverse cervical artery perforator propeller flap for reconstruction of supraclavicular defects. J Plast Reconstr Aesthet Surg 64:952-954, 2011. Propeller perforator flaps supplied by branches from the transverse cervical artery allow transport of skin from the back region to supraclavicular defects. This article described a soft tissue defect following resection of melanoma metastasis that was successfully reconstructed using a propeller flap based on a perforator originating from the anterior part of the cranial trapezius muscle. This technique should be considered as an alternative to commonly used muscle or myocutaneous flaps in selected cases.

Lynch JR, Hansen JE, Chaffoo R, et al. The lower trapezius musculocutaneous flap revisited: versatile coverage for complicated wounds to the posterior cervical and occipital regions based on the deep branch of the transverse cervical artery. Plast Reconstr Surg 109:444-450, 2002. The clinical role of the lower trapezius musculocutaneous flap varies in the literature. Many describe its use in the reconstruction of the lateral neck and facial regions, but very few refer to its use in the posterior cervical and occipital regions. Different vascular pedicles have also been described and effectively used. A retrospective analysis was conducted, reviewing the authors’ experience with 13 patients with complex open wounds to the posterior cervical and occipital regions that were treated with a lower trapezius muscle or musculocutaneous flap. All flaps were based on the deep branch of the transverse cervical artery. This pedicle was used to support a relatively large skin segment over the distal portion of the lower trapezius muscle, a margin that, in the authors’ experience, extends at least 1 cm beyond the muscular margin. Postoperatively, patients were evaluated based on complications, residual shoulder function, and aesthetic outcome. In addition to the clinical study, cadaveric dissection of the trapezius muscle was conducted on 22 specimens, and the vascular anatomy was confirmed by direct visualiza-
tion. The authors’ experience indicates that the lower trapezius myocutaneous flap, when based on the deep branch of the transverse cervical artery, provides a reliable alternative for the reconstruction of complicated wounds in the posterior cervical and occipital regions, with the added capability of providing richly vascularized tissue to compromised wounds as far cephalad as the vertex of the skull.


Foot reconstruction requires tissue that is durable and can withstand the extremes of pressure and stress. The trapezius myocutaneous flap had not been used previously as a free flap for foot reconstruction. In this report, the trapezius was used as an extended myocutaneous free flap for the reconstruction of a foot wound lacking adjacent and adequate recipient vessels. The extended trapezius flap may be one of the longest free flaps that can be harvested. The indications for the use of this flap are limited. In an extremity that lacks adequate recipient vessels adjacent to the defect, this flap can be extended so that more proximal vessels in the leg can be used as the recipient vessels without the need for vein grafts to bridge the distance. The donor site morbidity of this flap is minimal when the superior fibers of the trapezius muscle and its innervation are preserved.


Defects of the shoulder tip expose the glenohumeral and acromioclavicular joints and lead to scarring and contractures. Well-vascularized cover is required to restore function and appearance. The latissimus dorsi flap is commonly employed, but its use affects glenohumeral function, which is undesirable in a patient with a shoulder weak from an underlying pathologic condition. The authors described the extended lower trapezius flap for reconstructing the shoulder tip defects in three patients. This pedicled flap was based on the dorsal scapular artery and included the lower trapezius muscle and a long inferior fasciocutaneous extension. All flaps healed without complications, and all patients regained good shoulder function, with full range of motion. One patient who developed a tumor recurrence was treated with reexcision and latissimus dorsi flap reconstruction. The extended lower trapezius flap based on the dorsal scapular artery is well suited for reconstructing shoulder defects. With its fasciocutaneous extension, it has a long arc of rotation that is able to reach the shoulder tip. Shoulder morbidity is low, since only the lower trapezius is detached, minimizing disruption to scapulothoracic function. And because the latissimus dorsi is spared, glenohumeral function is not affected, and the option of the latissimus dorsi flap remains available for future use.


In defect reconstruction after radical oncologic resection of malignant chest wall tumors, adequate soft tissue reconstruction must be achieved along with function, stability, integrity, and aesthetics of the chest wall. The authors retrospectively evaluated the oncoplastic concept following radical resection of malignant chest wall infiltration with an interdisciplinary approach. Between 1999 and 2005, 36 consecutive patients (9 men and 27 women; mean age 55 years, range 20 to 78) were treated with resection for malignant tumors of the chest wall. Indications were locally recurrent breast carcinoma, thymoma, and desmoid tumor. Primary lesions of the chest wall were spinalioma, sarcoma, and non-small-cell lung cancer. There were distant metastases of colon and cervical cancer in one patient each. Soft tissue reconstruction was carried out using primary closure, an external oblique flap, a pectoralis major myocutaneous flap, latissimus dorsi myocutaneous flap, vertical or transversal rectus abdominis myocutaneous flap, free tensor fascia lata flap, trapezius flap, serratus flap, and one filet flap. In 15 reconstructive procedures microvascular techniques were used. On average, 3.4 ribs were resected. Stability of the chest wall was obtained with synthetic meshes. The latissimus dorsi flap is considered the flap of choice in chest wall reconstructions; however, alternatives such as the pectoralis major flap, VRAM/TRAM flap, free TFL flap, and serratus flap must also be considered. Low mortality and morbidity rates allow tumor resection and chest wall reconstruction, even in a palliative setting.


In surgical treatment of head and neck cancer, when local tumor recurrence or failure of the previous reconstruction method occurs, reoperation for reconstruction of complicated soft tissue defects can become a challenge for the plastic surgeon. The authors described their experience with the extended vertical trapezius myocutaneous flap for head and neck complicated soft tissue defects in nine patients ranging in age from 17 to 72 years. The causes of the defects were squamous cell carcinoma of the external ear, lip, larynx, and oral cavity floor; congenital hemifacial atrophy-temporomandibular joint ankylosis; synovial sarcoma at the mandibular ramus; and malignant fibrous histiocytoma at the posterior cranial fossa. Eight of the nine patients had previously been operated on using other flap procedures, including free flaps and/or distant pedicled flaps (pectoralis major and deltopectoral flaps). One patient had been operated on using a graft procedure. After failure of the previous flap procedures in four patients and tumor recurrence in five, the extended vertical trapezius myocutaneous pedicled flap was used as a salvage procedure. The mean flap size was 7 by 34 cm. The flap was based solely on the transverse cervical artery. Superior muscle fibers of the trapezius were preserved and the caudal end of the flap was extended from 10 to 13 cm beyond the caudal end of the trapezius muscle. Three weeks postoperatively, the pedicle was separated. No flap failure occurred. The donor sites were closed primarily. There were no disabilities with regard to shoulder motion. Tumor recurrence was observed in two patients. In conclusion, for complicated soft tissue defects of the head and neck, the extended vertical trapezius flap can be preferred as a salvage procedure because it is a simple, reliable, large flap that is located far enough from the damaged area.


Preexpanded flaps are a method to replace a larger postburn contracture area. The authors described the use of a preexpanded vertical trapezius myocutaneous flap for reconstruction of a severe mentosternal contracture in a 10-year-old boy with second- to third-degree burn wounds. A 500 cm³ rectangular-shaped tissue expander was inserted under the trapezius muscle via a lateral incision in first stage. Two months later, after serial expansion of the expander, the neck scar was excised. The preexpanded flap (27 by 9 cm) was harvested and rotated into the defect. The donor site could be closed primarily. The flap totally survived. The hospital stay was 7 days. After 6 months' follow-up, a significantly improved range of motion with good aesthetic outcome was achieved. The use of a preexpanded trapezius flap can provide thin, large, and pliable tissue for reconstruction of a severe mentosternal scar contracture with excellent functional outcomes.


The fibula free flap has become the dominant free flap for all mandible reconstructions, except in case of severe peripheral vascular disease. In these cases the authors propose to use the pedicled osteomuscular dorsal scapular flap as an alternative technique. This flap is an original technique, it is pedicled on the dorsal scapular vessels with harvesting of the medial border of the scapula and the lateral part of the rhomboid muscles. They carried out an anatomic study of the scapular region on 33 subjects to describe the surgical landmarks of the dorsal scapular pedicle. They determined the feasibility of this technique using ten fresh cadavers and performed this flap on three patients. In most cases (58%), the dorsal scapular artery passed very close to the superior angle of the scapula and ran lateral to the medial border of the scapula, in 42% of cases the artery divided into a lateral branch which ran deep to the medial border of the scapula and a medial branch which ran deep to the rhomboid muscles. In all cases an anastomosis between the dorsal scapular artery and the descending branch of the transverse cervical artery was present. In this technique, after harvesting the medial border of the scapula and the lateral part of the rhomboid muscles, the flap is transposed in the cervical region through a tunnel under the superior part of the trapezius. This technique was used in three patients after lateral resection of the mandible. The functional results were good, allowing preservation of the scapular elevation.
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>A large, flat, triangular muscle covering the posterior inferior half of the trunk. It extends from the humerus to the paraspinal and iliac area.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>Muscle: $25 \times 35$ cm; skin: $10 \times 22$ cm with primary closure.</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>Lower sixth thoracic vertebrae, sacral vertebrae, supraspinal ligament, and posterior iliac crest.</td>
</tr>
<tr>
<td><strong>Insertion</strong></td>
<td>Medial lip of the bicipital groove of the humerus.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Adducts, extends, and rotates the humerus medially.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Muscle, myocutaneous.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type V.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Thoracodorsal artery.</td>
</tr>
<tr>
<td><strong>Minor Pedicles</strong></td>
<td>Segmental paraspinal perforators; perforator of lumbar artery.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td>Thoracodorsal nerve.</td>
</tr>
</tbody>
</table>
Section 7F

POSTERIOR TRUNK

Latissimus Dorsi Flap

CLINICAL APPLICATIONS

Regional Use
- Head and neck
- Thorax
- Upper extremity
- Abdomen

Distant Use
- Head and neck
- Trunk
- Upper extremity
- Lower extremity

Specialized Use
- Intrathoracic reconstruction
- Functional muscle transfer (upper extremity, facial reanimation)
ANATOMY OF THE LATISSIMUS DORSI FLAP

A

Thoracodorsal artery

Branches of posterior intercostal artery

Branches of lumbar artery

Arterial supply to the latissimus dorsi muscle

B

Subscapularis muscle

Circumflex scapular artery

Posterior humeral circumflex artery

Teres minor muscle

Teres major muscle

Latissimus dorsi muscle

Subscapular artery

Upper subscapular nerve

Lower subscapular nerve

Thoracodorsal nerve (motor nerve)

Thoracodorsal artery

Lateral thoracic artery

Serratus branch of thoracodorsal artery

Long thoracic nerve

Serratus anterior muscle

Neurovascular anatomy of axilla

C

Branches of posterior cutaneous nerves

Branches of lateral cutaneous nerves

Sensory innervation to overlying skin

Fig. 7F-1

Dominant pedicle: Thoracodorsal artery

Minor pedicles: Segmental paraspinal perforators; perforator of lumbar artery
ANATOMY

Landmarks A large, flat, triangular muscle covering the posterior inferior half of the trunk. It extends from the humerus to the paraspinous and iliac area, passing below the tip of the scapula. Its medial origin is deep to the trapezius muscle. The lower portion of the muscle is superficial to the serratus posterior inferiorly and to the serratus anterior muscles in the midthorax.

Composition Muscle, myocutaneous. It is the largest, most expendable muscle in the body. Although the inclusion of the tenth rib has been described, this is not reliable in most surgeons’ hands and is not recommended.

Size Muscle: 25 × 35 cm; skin: 10 × 22 cm with primary closure.

Origin A broad aponeurosis joining the posterior layer of the thoracolumbar fascia and attaching to the spine of the lower sixth thoracic vertebrae, sacral vertebrae, supraspinal ligament, and posterior iliac crest. The muscle also has some small muscular slips of origin from the tenth, eleventh, and twelfth ribs, interdigitating with the slips of origin of the external oblique and serratus anterior muscles. The superior border of the muscle is largely free of attachments, with the exception of the attachment to the scapula; the lateral border is a free edge in which the deep surface merges with the underlying muscle fibers of the serratus anterior muscle.

Insertion The muscle fibers converge to form the posterior fold of the axilla, adjacent to the lower border of the teres major muscle. The broad muscular tendon then inserts into the medial lip of the bicipital groove of the humerus.

Function The latissimus dorsi muscle adducts, extends, and rotates the humerus medially. It is an expendable muscle, since function is preserved by the remaining synergistic shoulder girdle muscles.

Arterial Anatomy (Type V)

Dominant Pedicle Thoracodorsal artery

Regional Source Subscapular artery.

Length 8.5 cm.

Diameter 2.5 mm.

Location Enters the deep surface of the muscle in the posterior axilla 10 cm inferior to the muscle insertion into the humerus. The vessel then bifurcates into a transverse (upper) and a descending (lateral) branch that can be the basis for muscle splitting.

Minor Pedicle Segmental paraspinal perforators

Regional Source Perforators of the posterior intercostal arteries.

Length 1 to 2 cm.

Diameter 0.5 mm.

Location Adjacent to the site of the muscle origin into the lumbar vertebrae (paraspinal).

Minor Pedicle Perforator of lumbar artery

Regional Source Lumbar arteries.

Length 1 to 2 cm.

Diameter 0.5 mm.

Location Adjacent to muscle origin at lumbar vertebrae.
Venous Anatomy
Accompanying paired thoracodorsal veins and paraspinal venous perforators. The average diameter of the thoracodorsal vein is 3.5 mm.

Nerve Supply

Motor
The thoracodorsal nerve (C6 to C8) enters the muscle adjacent to a dominant vascular pedicle within the posterior axilla.

Sensory
The lateral cutaneous nerves arise from the intercostal nerves at the midaxillary line, and the posterior branches supply the skin overlying the latissimus dorsi muscle. These nerves are divided during flap elevation.

Vascular Anatomy of the Latissimus Dorsi Flap

Fig. 7F-2  A, Cadaveric dissection demonstrating the branching pattern of the vascular and neural supply of the latissimus flap seen on the underside of the muscle. Understanding of the pattern can allow muscle splitting for a partial muscle sparing approach. B, Anterior view of the dominant pedicle after release of the origin and insertion.

Dominant pedicle: Thoracodorsal artery (D)
i, Insertion; o, origin
Fig. 7F-2  C, Posterior view of the dominant pedicle after release of the origin and insertion.  
D, Posterior surface of the flap.  E, Radiographic view.  

Domestic pedicle: Thoracodorsal artery and venae comitantes (D)  
Minor segmental pedicles: Lateral row: branches of posterior intercostal artery and vein (S1); medial row: branches of lumbar artery and vein (S2)
FLAP HARVEST

Design and Markings

The skin paddle design should overlie the muscle for reliable perfusion. There are two basic designs, depending on tissue requirements and donor scar location. The largest skin island can be harvested in an oblique fashion; this is most useful in large reconstructions, chest wall applications, and free flaps. For breast reconstruction, where scar location and aesthetics are a priority, a transverse orientation is preferred to minimize the scar and carry a natural tissue roll within the relaxed skin tension line. A fleur-de-lis design can increase the amount of tissue harvested and still allow primary closure. In general, its use is not recommended, because the donor scar and contour deformity from harvest are greatly increased.

With the patient standing or sitting, forceful contraction of the latissimus dorsi muscle allows the anterior margin of the latissimus at the posterior axillary line to be visualized or palpated and marked. The tip of the scapula is marked with the patient’s arms at the sides; this denotes the superior margin of the latissimus dorsi muscle. The posterior vertebral column represents the posterior flap border. The posterior iliac crest is marked to determine the inferior margin of the flap. (Note: The inferior marking of a skin island is generally 8 cm superior to the posterior superior iliac crest.) The skin design is placed over the muscle in an oblique or transverse design, as noted earlier.
**Patient Positioning**

Several options are available for positioning the patient, depending on the reconstructive application of the latissimus flap. Most commonly, a lateral decubitus position is used, because it facilitates a two-team approach and aids in closure of the skin in the myocutaneous variant. It is critical to evaluate all areas of possible nerve compression and stretch to prevent nerve injuries. A beanbag is helpful for holding the torso in the proper position, and an axillary roll will prevent compression of the axilla. The arm may be draped in the field and rested on a Mayo stand or other support device. Alternatively, the arm may be positioned and draped off the field, especially if skin closure will not be an issue. In bilateral cases, it may be easier to harvest both flaps with the patient in the prone position and bank them in the axilla while changing the patient to a supine position for bilateral inset.
GUIDE TO FLAP DISSECTION

The area around the skin island is incised with a bevel away from the skin island, or a direct cutaneous linear incision is made overlying the surface of the muscle. Initial dissection exposes the superficial surface of the muscle. Elevation extends over the limits of the planned muscle dissection superiorly to expose the vascular supply and any skin tunnels required for rotation.

The superior fibers of the muscle are located below the tip of the scapula. The uppermost tendinous origin can be located under the inferior trapezius muscle fibers. These superior medial fibers of origin are divided, and the latissimus muscle is separated from the underlying paraspinal muscle fascia. Paraspinous perforators are ligated as the dissection proceeds laterally. The inferior extent of muscle harvest is then delineated by dividing the muscle inferiorly, taking care to separate the latissimus from the serratus posterior laterally where it is fused.
The entire muscle is then elevated toward the axilla. When the serratus anterior muscle is reached, the natural plane will carry the dissection deep to the serratus. This junction is typically denoted with a fatty layer that must be entered to maintain the dissection superficial to the serratus.

Superior elevation of the muscle exposes its deep surface in the posterior axilla. The thoracodorsal artery and vein are identified at the point of entrance into the muscle. The thoracodorsal nerve joins the vascular pedicle higher in the axilla; it is large and readily identified. If required, the tendinous insertion can be safely divided, because the neurovascular supply is deep at this point. This maneuver is required for free flap transfer and increases mobility for local advancement.
FLAP VARIANTS

- Reverse flap
- Muscle-sparing flap
- Thoracodorsal artery perforator (TAP, TDAP) flap
- Chimeric flap
- Functional muscle transfer

Reverse Flap

The reverse flap is designed for transposition as either a complete or a segmental muscle flap. A skin island can be carried if positioned over the muscle, usually over the superior third of the muscle. For a complete muscle flap design, the superficial surface of the muscle is exposed first. The muscle insertion is then divided within the axilla. After elevation of the fibers of insertion, the thoracodorsal artery, paired venae comitantes, and nerve are identified and divided. As the deep lateral surface of the muscle is visualized, dissection proceeds toward the midline of the posterior trunk. At 4 to 6 cm from the midline, the segmental pedicles from the posterior intercostal and lumbar arteries are visualized and preserved. The superior latissimus dorsi muscle fibers of origin are divided as required to obtain an adequate arc of rotation to the defect. With division of the superior muscle fibers of origin, the superior segmental pedicles are also divided as required. However, it is essential to preserve the inferior segmental pedicles to the muscle flap.

![Diagram of reverse flap with muscle insertion and thoracodorsal pedicle divided](image)

![Diagram of muscle transposed toward papaspinal perforators of posterior intercostal and lumbar arteries](image)

Fig. 7F-6
**Muscle-Sparing Flap**

One can take advantage of the major divisions of the thoracodorsal blood supply and innervation into transverse and longitudinal branches within the muscle and split the muscle, sparing viable, innervated muscle at the donor site. The location of the division can often be determined by inspecting the undersurface of the muscle (see p. 730) and splitting the latissimus from distal muscle up to this point. This technique is advantageous when a large, bulky flap with excess muscle is not required.

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**Fig. 7F-7**  
A, Schema for muscle splitting based on transverse and oblique branch pattern of the thoracodorsal pedicle.  
B, Design of skin paddle on the lateral muscle.  
C, The muscle is exposed and marked for splitting.  
D, The muscle has been split. The lateral muscle will carry the skin paddle, and the superomedial muscle is preserved. (Case courtesy Michel Saint-Cyr, MD.)
Thoracodorsal Artery Perforator (TDAP) Flap
The skin island normally carried with the latissimus flap can be isolated on a perforator of the thoracodorsal artery as a TDAP flap, sparing the latissimus muscle completely. Although morbidity from harvest of the latissimus muscle has not been well documented, some applications requiring less muscle bulk make this variant a reasonable flap choice.

Doppler identification of the perforators is possible but can be misleading, because perforators run a variable distance on the muscle fascia before they supply the subcutaneous tissues. The major perforators overlie the descending branch of the thoracodorsal artery within the muscle.

Dissection starts laterally with identification of the lateral muscle border and proceeds over the muscle. Care should be taken to look for a direct cutaneous branch of the thoracodorsal vessels winding around the lateral muscle border. Once a suitable perforator complex (artery and veins) is identified, the undersurface of the muscle should be locally exposed to determine the appropriateness of the perforator and the subsequent pedicle length. The more distal the perforator, the longer the pedicle length, and the longer the dissection. Motor nerves can be spared in this dissection. Lateral intercostal nerves can be harvested with the flap to make it a sensate flap. The pedicle length can be as long as 14 cm, and the flap can be used as a local rotation flap or as a free tissue transfer. As with the latissimus flap, a chimeric flap containing other components of the subscapular axis is possible.

Fig. 7F-8  A and B, TDAP design. The perforators overlie the course of the thoracodorsal artery.
Chimeric Flap

Flaps supplied by the subscapular axis of vessels (circumflex scapular and thoracodorsal) can be harvested as combined flaps on one vascular pedicle. Here the latissimus muscle can be combined with the serratus muscle on the thoracodorsal pedicle or can even be combined with scapular/parascapular flaps by extending the dissection of the pedicle to the subscapular vessels.

The muscle is elevated similar to a standard flap elevation. With the release of the muscle origin from the thoracic and lumbar vertebrae, posterior ribs, and lumbosacral fascia, the muscle is elevated superiorly toward the axilla. When the muscle’s deep surface is visualized, the thoracodorsal pedicle is easily identified, allowing proximal pedicle dissection. For a chimeric latissimus dorsi muscle and serratus flap, the serratus branch of the thoracodorsal pedicle is maintained, and the serratus muscle flap is elevated as described for the serratus muscle flap (see Section 6D). Pedicle dissection proceeds into the axilla to achieve adequate pedicle length.
For inclusion of the scapular/parascapular tissues in the flap, the dissection proceeds proximally to the takeoff of the circumflex scapular vessels. The scapular/parascapular flap having been previously dissected (see Section 7C), it must now be passed through the triangular space, often facilitated by division of the teres major muscle. The subscapular artery and vein may be dissected to their respective junctions with the axillary artery and vein to achieve maximum pedicle length.

**Functional Muscle Transfer**

The thoracodorsal nerve enters the latissimus dorsi muscle beneath its insertion in the posterior axilla. Release of the fibers of origin allows transposition of a functional muscle after restoration of a normal origin-insertion length-width relationship. The muscle may be transposed to the upper extremity with reattachment of muscle origins to the arm to restore either elbow flexion or extension. The muscle is also suitable for transposition to the anterior chest wall to replace an absent (Poland’s syndrome) or injured pectoralis major muscle.

**ARC OF ROTATION**

**Standard Flap**

The point of rotation is located at the posterior axilla where the thoracodorsal pedicle enters the muscle. The muscle then has a posterior arc of rotation to the neck and occipital and parietal skull and across midline in the upper thorax. The anterior arc of rotation includes the ipsilateral chest and sternum, middle and lower thirds of the face, and superior abdomen. The standard arc of rotation is extended approximately 5 to 10 cm by division of the latissimus dorsi tendinous insertion and mobilization of the vascular pedicle (i.e., a division of the branch to the serratus anterior muscle and branch of the circumflex scapular artery).
Anterior Arc of Standard Flap

Arc to anterior thorax with insertion intact

Arc after release of insertion

Fig. 7F-9

Posterior Arc of Standard Flap

Arc to posterior thorax with insertion intact

Arc after release of muscle insertion

Fig. 7F-9
Reverse Flap
After the dominant vascular pedicle is divided, the point of rotation is along the lateral and/or medial row of minor pedicles. The muscle will then reach across the midline of the posterior trunk. Standard reverse rotation involves division of the humeral insertion, sacrifice of the thoracodorsal bundle, and transposition of the muscle like an open book. The muscle will survive based on its paraspinal perforators from the posterior intercostal and lumbar arteries.

An alternative to flap elevation when muscle requirements are not so great (such as exposed hardware) involves midline release of the latissimus fascia only. This allows mobilization of the muscle for a few centimeters without division of the thoracodorsal bundle or paraspinal perforators, maximizing the blood supply and minimizing morbidity. It also allows secondary use of the latissimus muscle, if needed later.
FLAP TRANSFER

Standard Flap
The muscle reaches the superior abdomen and anterior chest wall through a subcutaneous tunnel between the donor and recipient sites. The latissimus muscle will reach the head and neck region through a subcutaneous tunnel between the recipient site and the lateral clavicle. The arc of rotation can be improved by tunneling under the pectoralis major fibers laterally. For defects over the mediastinum, the tunnel will extend beneath the skin and either superficial or deep to the pectoralis major muscle, if this muscle is still present.

For intrathoracic defects, resection of the second or third rib segment at the midaxillary line allows the muscle to enter the superior mediastinum. A similar window in the fifth to sixth intercostal space will allow muscle transposition into the middle and inferior mediastinum when less muscle is available. The chimeric serratus with latissimus flap can add needed intrathoracic volume.

Reverse Flap
The reverse flap is designed directly adjacent to the defect and does not require a separate tunnel for transposition into the posterior trunk defect. A complete muscle flap can be used without a skin island. The muscle is advanced like opening a book, with the superficial surface of the distal muscle flap facing into the deep surface of the defect. If a complete muscle flap is used with a skin island, it is generally necessary to rotate the flap without kinking; planning the orientation of the skin island dictates how much rotation will be necessary.

FLAP INSET

Pedicle Flap
The rotated flap should be inset without tension, evenly distributing the muscle. If the flap reaches the defect without division of the tendinous insertion, this attachment should be left to protect inadvertent tension on the pedicle. The tunnel must be wide enough that there is no compression of the pedicle postoperatively. Division of the thoracodorsal nerve should be considered if muscular contraction postoperatively would adversely affect healing. The nerve is maintained for functional transfer and in cases in which the bulk of the muscle needs to be maintained.

Free Flap
Inset of the muscle is relative to the pedicle and the microvascular anastomosis. It is recommended that the muscle be inset on some tension to re-create near-original dimensions, which will improve blood flow through the flap. For a TDAP inset, no muscle is available to anchor the flap, and the flap must be carefully secured to its recipient site with superficial fascia and dermis.

DONOR SITE CLOSURE

All Flap Variants
Direct donor site closure is recommended. Correct planning can avoid the use of skin grafts, which result in contour defects. A skin island 7 to 9 cm wide will generally permit primary closure. Wider islands can be closed directly in selected patients, depending on the amount of skin laxity. The contour defect in the back is minimal after removal of the latissimus dorsi muscle. The initial fullness seen in the reverse flap settles with time. Upper arm abduction and medial rotation are preserved by the remaining shoulder girdle muscles, including the pectoralis major, subscapularis, teres major, and coracobrachialis muscles.
CLINICAL APPLICATIONS
This 44-year-old patient had a previous TRAM flap reconstruction of the left breast and an implant reconstruction of the right breast that was contracted; her breasts did not match, even in a bra.

Fig. 7F-11  A, The patient requested autologous-only reconstruction for the right breast. B, A myo-cutaneous latissimus flap with subscarpal extended fat harvest was chosen, with the flap design in the relaxed skin tension lines. C-E, The results are shown 6 month postoperatively. F, Donor site at 6 months. (Case supplied by MRZ.)
This 50-year-old woman was diagnosed with an invasive right breast cancer. She had symptomatic macromastia and desired a contralateral reduction. She was offered an autologous reconstruction with a myocutaneous latissimus flap to match the reduced breast. The amount of reduction was determined intraoperatively based on the amount of latissimus tissues transferred.

Fig. 7F-12  A, A Wise pattern breast reduction was planned for the left breast, and a partial skin-sparing mastectomy for the right breast. B, The skin design chosen was an oblique pattern, maximizing the amount of tissue transferred for building the mound and not requiring an implant. C, The result is seen 9 months postoperatively with excellent symmetry in shape and volume. D, Donor scar at 9 months. Although the thicker scar and contour deformity did not bother the patient, this illustrates the difference from a transverse skin paddle in natural relaxed skin tension lines, which leaves a better scar and minimal contour deformity. (Case supplied by MRZ.)
This 39-year-old woman had a history of right breast cancer and previous pedicle TRAM flap reconstruction. She presented with a radiation-induced sarcoma of the chest. In this case, all abdominal options had been exhausted. Normally, we would consider the latissimus dorsi or the omentum as rotational options, but there was not enough tissue for such a large defect. The largest available block of tissue was a chimeric flap, harvesting the latissimus and the serratus on their common blood supply. A large chimeric flap from the leg would also have been possible, but deforming. Here the chimeric flap, transferred as a free flap to the neck vessels, provided adequate tissue, bolstered with nearby omentum in a vest-over-pants fashion. The key in this case was supplying an adequate amount of well-vascularized tissue to accomplish the reconstruction.

Fig. 7F-13  A, Preoperative appearance. B, The chest wall and abdominal wall specimen, including diaphragm. C, Clinical defect. The chest, abdomen, and diaphragm were first repaired with Gore-Tex mesh. D, Contralateral chimeric latissimus and serratus flaps on their thoracodorsal pedicle. E, Flaps were inset after microsurgical revascularization to the neck. The omentum was used to close the inferior portion of the wound, all of which was skin grafted. F, Postoperative appearance at 6 months, with no bulges or hernias. (Case supplied by MRZ.)
This 4-year-old boy was injured in a lawn-mower accident. Heel reconstruction can be managed with regional flaps (such as sural) or free flaps. Free flaps can be skin based (for example, the radial forearm) or muscle based, with skin or skin grafting to the muscle. There are advantages and disadvantages to all approaches and vocal supporters for each technique. In this case, a myocutaneous latissimus free flap was chosen to minimize donor site morbidity and to provide as durable a reconstruction as possible. It is not uncommon to need revisional procedures to allow normal shoes to be worn and to improve cosmesis, especially in areas where the pedicle was left bulky at the first operation.

Fig. 7F-14  A and B, Appearance of the heel with missing soft tissue and exposed calcaneus and fascia. C, Latissimus free flap design based on a template of the foot defect. D, Latissimus free flap inset. Excess muscle was skin grafted and the bulk was left for 4 months, when it was directly debulked. E, Three months after debulking. (Case supplied by MRZ.)
This 34-year-old woman underwent tissue expander reconstruction. Although she did not receive radiation therapy, her mastectomy skin became thin, and ultimately her expander was exposed. Options at this point included removal of the expander and closure, with ultimate reinsertion of a tissue expander with or without the use of acellular dermal matrix, conversion to autologous-only reconstruction, or salvage of the expander with a latissimus myocutaneous flap. She underwent latissimus salvage, during which we took the opportunity to remove all suspect thin skin and “patch” the area with muscle cover and adequate skin from the back. Notice how the flap design allows the donor scar to be well hidden in her clothes. This flap is advantageous also for partial breast reconstruction when the partial mastectomy defect can be “patched” with a rotational latissimus dorsi flap.

Fig. 7F-15  A, The patient had threatening implant extrusion in the left breast and underwent salvage with a latissimus flap. B, A transverse flap design was used in the relaxed skin tension line. C-E, Her result is shown 2 years postoperatively. F, Her donor scar is seen 3 weeks postoperatively. (Case supplied by MRZ.)
The latissimus dorsi is an expendable muscle in patients with intact, synergistic shoulder girdle muscles. However, in patients with contralateral shoulder girdle paralysis (such as after a craniectomy for tumor extirpation) or extremity paralysis from spinal cord injury, the latissimus dorsi muscle function may be essential. Alternative flap choices should be considered.

Denervated latissimus dorsi muscle has thin, pale muscle fibers, even though the intramuscular vascular system is intact. Dissection is initiated on the inferior aspect of the proposed island to identify the underlying muscle. Inadvertent incision through the muscle will not injure the proximal muscle circulation and allows the surgeon to alter the plane of dissection to preserve the superior muscle with the flap vascular pedicle.

The serratus branch to the latissimus dorsi should not be divided until the proximal subscapular–thoracodorsal artery and vein are identified. If the proximal thoracodorsal artery and vein have been divided previously, the muscle will survive transposition based on the serratus muscle branches with retrograde blood flow. The flap will reach the anterior chest for chest wall or breast reconstruction if dissection is limited proximally to this branch point.

During the initial muscle dissection, care is taken to separate the latissimus muscle from the superficial surface of the scapula and its associated serratus anterior muscle. Failure to maintain the dissection superficial to the scapula may result in elevation of the latissimus muscle with the underlying serratus anterior muscle. This zone of fusion is heralded by a fatty plane that must be entered.

If the tendon of insertion is divided, only the dominant vascular pedicle will limit the arc of rotation. Excessive tension on the muscle flap may disrupt the vascular pedicle, so the muscle and tendon must be carefully resecured after transfer.

The tunnel should have adequate dimensions to prevent flap compression. In general, the space available should be twice the volume of the flap located within the tunnel between the donor site and the site of flap inset.

Precise identification of the segmental vascular pedicles is essential during reverse latissimus myocutaneous flap transposition. If time permits, an initial delay procedure involving division of the thoracodorsal pedicle can be performed 2 weeks before harvest.

A pillow holding the elbow in a position of shoulder abduction will prevent pedicle compression postoperatively when transposition is to the anterior chest or head and neck.

Seroma in the back donor site is common, and a minimum of two large drains is recommended for 2 weeks, or until the drainage is less than 25 ml per day. Tissue glue and sequential sutures have been used by some to minimize this complication.

The latissimus dorsi flap is the flap of choice when pediatric free tissue transfer is needed for reconstructive challenges requiring a large flap with low morbidity.
EXPERT COMMENTARY
Michael R. Zenn

Indications
The latissimus dorsi flap is one of the most versatile flaps available to reconstructive surgeons. It is both the largest muscle and the most expendable, and has for decades proved to be a valuable donor site both as a pedicled flap and a free flap. Although the anatomy and the varied uses of the flap are well outlined in this chapter, variations do exist in the harvest of the muscle. I would like to point out one of the more valuable ones I use routinely in breast reconstruction.

Anatomic Considerations
The goal in breast reconstruction with a latissimus flap is delivery of the muscle and a skin paddle with minimal scar morbidity in the back. In women undergoing breast reconstruction, that means a scar that will not be visible in most clothes. I favor the low transverse pattern of skin design, centered between the scapular tip and the posterior iliac crest, along the relaxed skin tension line. If there is a roll of excess fat in the back, it is usually here. The problem with this skin design is that it limits exposure in the upper third dissection, where pedicle identification is essential and full release is required for an adequate arc of rotation to the chest.

Recommendations
Technique
In breast reconstruction I like to start the dissection of the latissimus from the chest recipient site with a lighted retractor, but certainly a headlight or endoscope would work just as well. The subcutaneous tunnel from recipient to donor site is marked and dissected. This dissection plane will take the dissection naturally on the serratus anterior muscle before the lateral border of the latissimus muscle is reached. I follow this plane, which leads under the latissimus muscle, and within 3 cm the thoracodorsal pedicle can be seen, distal to the serratus branch of the thoracodorsal vessels.

Once past these vessels, it is an easy dissection in areolar tissue completely underneath the latissimus to the medial border, where the subcutaneous plane is reestablished, releasing the muscle medially. Next, the dissection is turned inferiorly, where the latissimus is separated from the serratus anterior under direct vision as far as possible until visualization becomes difficult. The lighted retractor is removed, and dissection of the anterior surface of the muscle is quickly and easily performed. Care must be exercised not to undermine the intended skin paddle. When a two-team approach is used, the superior skin paddle is incised first to prevent this, and the remainder of the time is spent dissecting the distal flap so that both teams can finish about the same time, cutting harvest time in half.

Take-Away Messages
This flap design, degree of dissection, and arc of rotation allow the flap to easily reach the anterior chest for breast reconstruction. This also preserves the important serratus branch of the thoracodorsal vessels, which are able to supply the flap by retrograde flow when the thoracodorsal vessels have been divided during axillary lymph node dissection. The scar quality and placement are excellent.
Bibliography With Key Annotations


The authors reported study to assess women’s preference for the latissimus dorsi donor site location, the reasons for donor site choice, and the correlation between donor site location preference and factors such as age, body mass index, body image, and clothing options. Two hundred fifty women between 20 and 80 years of age were surveyed. Participants analyzed patients’ pictures and ranked the scar locations from most desirable to least desirable. The reason for their preference and additional factors were assessed. The data were then collected and analyzed. The low and middle transverse donor sites were the most preferred sites, 54% and 22%, respectively. The most common reasons for choosing a donors site were ability to conceal the scar in a low-back top and contour improvement. Women younger than 50 years were more concerned about the ability to conceal the scar (64%). Women older than 50 years were focused on contour improvement (40%) and concealing the scar while clothed (42%). No direct correlation with age, body mass index, body image, or clothing options was seen.


A latissimus dorsi myocutaneous flap was used in 60 patients for immediate reconstruction following head and neck tumor ablation. The distribution of surgical defects was as follows: floor of mouth (22), retromolar trigone (11), pharyngeal wall (9), segmental esophagus (9), temporozygomatic (7), and full-thickness cheek (2). The flap was routinely tunneled beneath the pectoralis major and superficial to the pectoralis minor and clavicle to reach the head and neck defect. The authors recommend design of the skin island on the superior two thirds of the muscle surface for best blood supply. A small skin island located over the inferior third of the muscle may not have adequate circulation following transposition to the head and neck region.


The authors presented a series of 13 cases of partial superior latissimus flap, which has the following advantages: (1) small or medium size, (2) large-caliber vessels, (3) a potentially long vascular pedicle, (4) preservation of the majority of the latissimus muscle in situ, (5) preservation of the dorsal thoracic silhouette of the back, (6) the potential for neurotization and sensory or functional muscle reconstruction, and (7) use as a myocutaneous flap by including the overlying skin territory.


The authors presented a study to assess a single surgeon’s technique and outcomes with the extended latissimus dorsi musculocutaneous flap. Patients who underwent unilateral or bilateral, delayed or immediate extended latissimus breast reconstruction were included in this retrospective study. Epidemiologic data, tumor diagnosis, mastectomy type, length of hospital stay, flap complications, donor site complications, and length of follow-up were recorded and analyzed. Flap design consisted of a near-transverse elliptical skin paddle, the latissimus muscle, and the fat pad deep to the superficial thoracic fascia and overlying the latissimus muscle. Twelve reconstructions were performed in 10 patients, with bilateral reconstructions in 2 patients. Eight were immediate, and 4 delayed. Mean patient age was 60 years (range 47 to 77 years). Mean body mass index was 33.2 kg/m² (range 25.2 to 40 kg/m²). Four patients received adjacent radiation therapy before breast reconstruction. The mean skin paddle area was 22.3 by 8.6 cm (192.3 cm²). The mean follow-up was 20.6 months. Flap complications developed
in 2 of 12 flaps (16.7%); both were partial flap losses requiring reoperation. Donor site complications developed in 8 of 12 donor sites (66.7%). The most common donor site complication was seroma formation. Partial mastectomy skin flap necrosis occurred in 5 patients. The extended latissimus dorsi myocutaneous flap can provide total autologous breast reconstruction in select cases, specifically in women who are poor candidates for implant-based reconstruction and in those with contraindications to an abdominal flap. Safe, large-volume breast reconstruction is possible by harvesting a flap that includes only fat tissue directly overlying the latissimus muscle.


Innovative surgical techniques developed by surgical oncologists have changed the landscape of mastectomy defects. Latissimus dorsi myocutaneous flap–based breast reconstruction provides a reliable foundation for breast reconstruction. The authors presented a study evaluating differential skin island designs with latissimus dorsi myocutaneous flap breast reconstruction and provided an algorithmic approach to breast reconstruction that is applicable to a broad spectrum of mastectomy defects.


The latissimus dorsi myocutaneous donor site was preexpanded with a 1000 mm oval tissue expander. Expansion was completed in 12 weeks. A large skin island was subsequently used with the underlying latissimus dorsi muscle for coverage of an anterior chest wall mastectomy defect with previously placed skin grafts. The donor site was closed directly without the necessity for skin grafts. The authors recommended preexpansion of myocutaneous flaps if direct closure of the donor site may not be possible.


Thin patients have fewer autologous options in postmastectomy reconstruction and are frequently limited to device-based techniques. The latissimus dorsi flap remains a viable option with which to provide autologous coverage, although for certain patients the donor scar can be a point of contention. The scarless latissimus dorsi flap is a way of mitigating these concerns. The authors presented their 6-year single-surgeon experience with scarless latissimus dorsi flap reconstruction. Charts from 2003 to 2009 were reviewed for demographic characteristics, nonoperative therapies, and short- and long-term complications. Results were compared with historical data. Thirty-one patients with 52 flaps were identified. Fifty-one flaps were immediate reconstructions; these patients had an average age of 47 years and BMI of 22.8. Thirteen patients were treated with chemotherapy and 2 underwent radiation therapy, 2 preoperatively. The single drain was removed, on average, at 21 days. Complications included 3 hematomas (5.8%), 2 capsular contractures (3.8%), and 2 infections (3.8%). The average time to secondary reconstruction was 143 days. There were 5 unplanned revisions (9.6%). There were no flap failures or tissue expander losses.


The authors studied blood flow between the serratus anterior arterial branch to the latissimus dorsi via the thoracodorsal artery during intraoperative dissections in patients undergoing mastectomy and in the primate model. Reversal of flow after a division of a thoracodorsal artery and vein was clearly demonstrated in these studies. Based on their data, it appears safe to rely on the crossing branch from the serratus anterior into the thoracodorsal artery as the dominant vascular pedicle for transposition of the latissimus dorsi in selected patients.

In this prospective study, the authors set out to define the impact on shoulder function and to assess recovery time scales compared with preoperative values. Shoulder range of motion, strength, function, and pain were assessed prospectively in 22 subjects who had latissimus dorsi muscle flap breast reconstruction. Assessments were carried out preoperatively and then at 6 weeks, 6 months, and 1 year postoperatively using standardized objective assessments. The results demonstrated no significant loss of range of motion, strength, function, or pain at 1 year. However, strength, disability scores, neural glide, and discomfort were still abnormal at 6 months and then normalized at 1 year. It was noted that the extended latissimus dorsi flap tended to have poorer scores and recovery compared with a latissimus dorsi flap and implant.


A series of eight parascapular fasciocutaneous and latissimus dorsi muscle conjoined free flaps were reported. This combination allows the creation of an extremely large cutaneous flap from the dorsal thorax while ensuring survival of both the muscle and skin portions in their entirety.


Between 2002 and 2004, 22 patients who had a partial breast reconstruction using a pedicled thoracodorsal artery perforator flap were enrolled in a functional study to evaluate shoulder function postoperatively. Latissimus dorsi muscle strength, shoulder mobility, and latissimus dorsi thickness were measured by using the MicroFet2, a goniometer, and ultrasound examination, respectively. The measurements of the operated and contralateral (unoperated) sides were analyzed statistically. When comparing the operated sides to the unoperated sides, latissimus dorsi strength seemed to be maintained after surgery. Shoulder mobility was also similar in all movements, but both active and passive forward elevation and passive abduction were reduced significantly after surgery, and latissimus dorsi thickness was not affected by harvesting the thoracodorsal artery perforator flaps. No seroma formation was found in any of the donor sites.


A thoracodorsal artery perforator flap was harvested in 90 cases. The perforators were unsuitable in 10 flaps. Unidirectional Doppler imaging was used exclusively in 92% of cases to map the perforator preoperatively and was felt to add greatly to the efficiency of flap harvest. The average flap size was 20 by 8 cm. Average operative time for flap harvest was 80 minutes. Perforators were located at 8 to 13 cm from the axillary crease (average 10.8 cm).


Five technical modifications in surgical technique, including orientation of the skin island along the relaxed skin tension lines, harvesting the deep layer of fat with the flap, cutting the thoracodorsal nerve, partially dividing the insertion of the muscle, and using a staged expander/implant sequence, are included in an overall surgical strategy designed to reconstruct the breast in both delayed and immediate settings. As a result of these technical modifications, a thin line and smooth donor site scar is created in the back. The flap advances completely to the breast because of the partial release of the insertion of the muscle, and the volume provided by the flap is increased by keeping the deep layer of fat attached to the flap. This more effectively softens the contours of the reconstructed breast. Breast animation is minimized as a result of sectioning of the thoracodorsal nerve, and the consistency and quality of the result are improved by using a staged tissue expander/implant strategy.

The authors’ goal was to develop an updated and comprehensive algorithm for skull base reconstruction based on data from the 10-year period following their initial report. Reconstructive outcomes were analyzed from 250 patients undergoing skull base reconstruction from 2000 to 2009. Thirty-nine local or regional pedicled flap reconstructions and 211 free flap reconstructions were performed. Free flaps were usually selected over pedicled flaps for patients with a history of prior surgery, irradiation, or chemotherapy. Reconstructions were performed for 36 region I defects, 39 region II defects, 124 region III defects, and 51 defects involving more than one region. Complications occurred in 29.6% of patients. There were no significant differences in the overall complication rates between pedicled and free flap reconstructions. The recipient-site complication rate decreased from 31% in the authors’ prior report to 18.4%. A facial nerve repair was performed in 30 patients. By 12 months, 75% of patients had signs of reinnervation. Recovery was not significantly less likely in patients with preoperative weakness, postoperative irradiation, or age 60 years or older.


The treatment of scalp tumors was documented in 60 patients over a 10-year period. Data regarding tumor type, size, and localization; reconstructive procedure; oncologic, functional, and aesthetic outcome; and complications were collected and analyzed retrospectively. These data were correlated to recurrence and survival rates. The findings extracted from the data were amalgamated to produce the proposed reconstructive algorithm. Five reconstructive categories were defined and their application described in an algorithmic approach. Indications, limitations, and adequate reconstructive procedures for each category were identified. The most important decisions are when to use local flaps versus primary closure and when to use free tissue transfer.


Free sensate thoracodorsal artery perforator flaps that include the posterior divisions of the lateral cutaneous branches of the intercostal nerves have been described. The authors used preoperative color Doppler sonography to identify the nerves and demonstrate its clinical value. Fourteen free sensate thoracodorsal artery perforator flaps were collected. Preoperative color Doppler sonography was used to identify the locations of thoracodorsal artery perforators and the courses of the posterior divisions of the lateral cutaneous branches of the intercostal neurovascular bundles. These posterior divisions were preserved on flaps and classified into three types. Type A and B nerves sprouted cutaneous perforating fascicles over the lateral region of the latissimus dorsi muscle. Type C nerves went through the region without any dominant perforating fascicle. Twenty-one nerves were mapped, and 24 were found during surgery. The sensitivity of preoperative color Doppler sonography was 87.5%. Of the 24 nerves, nine were type A (37.5%), 12 were type B (50%), and three were type C (12.5%). Ten of the 14 patients (sensate group) showed better tactile recovery at both the center and the periphery of the flap than the other 10 patients who underwent reconstruction with nonsensate flaps.


Breast conservation therapy for the management of women with breast cancer continues to grow in popularity. To preserve cosmesis or broaden the indications for breast conservation therapy in some situations, plastic surgeons are now being challenged with the reconstruction of partial mastectomy defects. Numerous techniques exist, either at the time of resection or following radiation, and the decision of which to use depends on breast size, tumor size, and tumor location. Women with unfavorable defects...
in smaller breasts will often benefit from volume replacement techniques, such as local fasciocutaneous or myocutaneous flaps, without the need for a symmetry procedure. Women with moderate or larger breasts (with or without ptosis) and the potential for an unfavorable result also have the option for volume displacement procedures using local tissue rearrangement techniques to reshape the breast mound. As these are volume reduction procedures, they often require a contralateral procedure for symmetry. The extent of resection (lumpectomy versus quadrantectomy) will also influence the type of reconstruction. Patient selection, surgical technique, margin status, and appropriate follow-up are crucial to maximize both oncological safety and cosmesis. The reconstruction of partial mastectomy defects will likely gain popularity as we continue to demonstrate safe and effective treatment algorithms with larger series and longer follow-up in an attempt to minimize locoregional disease and maximize cosmetic outcome.


Distal anterior chest wall defects remain a challenge for the reconstructive surgeon. To reconstruct this region, the most commonly used flaps are the pectoralis and rectus abdominis flaps. When these flaps cannot be used, the pedicled latissimus dorsi flap and the omentum flap are suitable options. The use of the pedicled latissimus dorsi flap for chest wall reconstruction was first described by Tansini in 1906 and was subsequently popularized by Olivari in 1976. Since then, the latissimus dorsi flap has gradually evolved, with many modifications and refinements described in the literature. In the traditional pedicled latissimus dorsi flap, the skin paddle is typically placed in the mid to upper back region. With this location, the arc of rotation and reach of the skin paddle can make it difficult to cover anterior chest wall defects. Thus when the latissimus dorsi flap is used for coverage of the anterior chest wall, skin grafting over the muscle is often required, resulting in less than optimal cosmetic results. To provide a latissimus dorsi flap with a wider arc of rotation and increased skin paddle reach to and past the chest anterior midline, they designed the low skin paddle pedicled latissimus dorsi flap. The preoperative design and vascular basis of the flap were discussed and a case report was presented.


The results of 100 cadaver dissections of the subscapular-thoracodorsal arterial system are presented. In 94% of dissections, the thoracodorsal artery originated from the subscapular artery. In the remaining 6%, thoracodorsal arteries had an anomalous origin, although in each instance the aberrant vessels were of satisfactory dimensions to support the latissimus dorsi flap. In 99% of dissections, significant branches of the thoracodorsal artery to the serratus anterior muscle were found, confirming the viability of the serratus muscle for either transposition or transplantation based on the subscapular-thoracodorsal arterial axis. In 47% of dissections, a direct cutaneous branch from the thoracodorsal artery was demonstrated, the forerunner of the TDAP.


The latissimus dorsi flap holds an important role in reconstructive surgery. Despite its widespread use as a free flap, donor site morbidity can still be problematic. A muscle-sparing version of the latissimus dorsi free flap can help alleviate donor site morbidity while still providing an excellent tool for reconstruction. The authors investigated the vascular anatomy and clinical results of the free muscle-sparing latissimus dorsi flap based on the descending branch of the thoracodorsal artery. They also reported the vascular anatomy of the transverse branch muscle sparing latissimus dorsi flap and compare this to the descending branch version of the latissimus dorsi flap.

The pedicled descending branch muscle-sparing latissimus dorsi flap with a transversely oriented skin paddle presents distinct advantages in breast reconstruction, including reduced donor site morbidity and greater freedom of orientation of the skin paddle. The authors reported the anatomic basis, surgical technique, complications, and aesthetic and functional outcomes following use of this flap for breast reconstruction in a retrospective study of 20 patients who underwent breast reconstruction with a pedicled muscle-sparing latissimus dorsi myocutaneous flap. Indications for surgery included breast reconstruction after mastectomy, lumpectomy, and irradiation and for correction of implant-related complications. Case-note reviews were performed, as was a functional evaluation consisting of a patient questionnaire, a Disabilities of the Arm, Shoulder, and Hand form, postoperative range-of-motion analysis, and instrumented strength testing comparing the operated and nonoperated sides. Aesthetic evaluation of the donor site was conducted by all patients. An anatomic study of 15 flaps harvested from fresh cadavers was performed to determine the location of the bifurcation of the thoracodorsal artery and the course of its descending branch. Twenty-four descending branch muscle-sparing latissimus dorsi flaps were harvested. All donor sites were closed primarily, with skin paddle sizes ranging up to 25 by 12 cm. There was one case of minor flap tip necrosis and no instances of seroma. There was no statistically significant difference in strength or range of motion of the shoulder joint when comparing the operated to the nonoperated side. Two patients reported minor functional impact following surgery.


A series of 51 muscle flap procedures were performed in 42 patients (serratus anterior flaps, 16 patients and 23 flaps; latissimus dorsi flaps, 16 patients and 18 flaps; pectoralis major muscle flaps, intercostal muscle flaps, and rectus abdominis flaps, 3 patients each; omental flap, 1 patient). Because of the excellent blood supply of extrathoracic muscle flaps and their ability to reach any place in the pleural cavity, they represent an ideal tissue with which to fill the contaminated pleural space.


For innervated functional muscle transplant procedures, it is essential that the surgeon be aware of the length of nerve pedicles available for nerve anastomosis. For the latissimus dorsi muscle, the thoracodorsal nerve divides into two funicles that separately innervate the medial and lateral portions of the muscle. This suggests the possibility of a multiple, segmentally innervated latissimus dorsi muscle transfer. The branching and length of the thoracodorsal nerve distal to the bifurcation have not been described. This surgical-anatomic study presented anatomic data on these practical/clinical issues. Eleven latissimus dorsi muscles were dissected in eight adult embalmed human specimens. The thoracodorsal neurovascular bundle was dissected from insertion to proximal of the bifurcation. Measurements were taken indirectly from standardized photographic images and analyzed with ImageJ and standard spreadsheet software. The authors concluded that the separate neurovascular branches and its minimal pedicle length make the latissimus dorsi muscle very suitable for single functional free muscle transfer, using only the lateral part of the latissimus dorsi muscle, and double functional free muscle transfer using only one vascular pedicle.

Full-thickness burns involving the antecubital area result in severe contractures. Functional impairment is inevitable if the affected areas are not managed properly. Proper treatment requires complete release and radical excision of the scar tissue, followed by reconstruction using durable tissue that will not contract during long-term follow-up. Nine patients with flexion contractures were reconstructed with pedicled thoracodorsal artery perforator flaps between 2004 and 2008. All of the patients were men; their ages ranged from 20 to 23 years (mean 21.4 years). The size and orientation of the skin islands were planned according to the defect size and orientation. The size of the flaps varied from 6.5 to 9.0 cm in width (mean 8.0 cm) and 16.0 to 21.0 cm in length (mean 20.0 cm). All of the patients were followed up for 6 to 12 months (mean 9.3 months). All of the flaps used on the postburn antecubital contractures survived completely. Minimal transient venous congestion occurred in two flaps during the early postoperative period. A complete range of motion at the elbow joint was achieved in all patients by the end of the reconstruction period.


The latissimus dorsi was transferred to the anterior compartment of the upper arm based on its thoracodorsal neurovascular pedicle with reattachment of its origin to the biceps tendon and its insertion into the coracoid process so that the muscle transfer functioned as an elbow flexor. This flexorplasty technique was used in eight patients with flexor paralysis of the elbow due to brachial plexus injury (2) and poliomyelitis (6). All patients achieved active elbow flexion with a range of 105 to 140 degrees. The authors recommended this technique over traditional flexorplasty techniques, including the pectoralis major and triceps muscles.
ANATOMIC LANDMARKS

**Landmarks**
The paraspinal muscles, otherwise known as the *erector spinae*, consist of a complex block of muscle lying on either side of the spinal processes of the vertebrae extending from the nuchal line of the skull to the sacrum.

**Size**
60 cm long × 6 to 8 cm wide.

**Origin**
Muscles arise segmentally from the sacrum and iliolumbar fascia and the transverse processes of the vertebrae and medial ribs.

**Insertion**
Muscles insert segmentally into transverse processes of the spine, all the way to the occiput of the skull.

**Function**
Extension and lateral flexion of the spine.

**Composition**
Muscle.

**Flap Type**
Type IV.

**Dominant Pedicle**
Segmental and segmental intercostal arteries.

**Minor Pedicle**
Secondary lateral perforators.

**Nerve Supply**
*Segmental spinal*: Cervical to lumbar.
Section 7G

POSTERIOR TRUNK

Paraspinous Flap

CLINICAL APPLICATIONS
Regional Use
Coverage of spinal wounds
ANATOMY OF THE PARASPINOUS FLAP

A

Semispinalis capitis muscle
Semispinalis cervicis muscle
Semispinalis thoracis muscle
Multifidus muscle

Paraspinal muscles

B

Longissimus capitis muscle
Longissimus cervicis muscle
Longissimus thoracis muscle
Segmental intercostal arteries

Intercostal arterial supply

C

Medial perforator
Segmental intercostal arteries
Secondary lateral perforator

Cross-section of neurovascular anatomy of paraspinal muscles

D

Secondary lateral perforators
Segmental intercostal arteries

Intercostal nerve supply

Fig. 7G-1

Dominant pedicle: Segmental and segmental intercostal arteries
Minor pedicle: Secondary lateral perforators
ANATOMY

Landmarks  The paraspinal muscles, otherwise known as the erector spinae, consist of a complex block of muscle lying on either side of the spinal processes of the vertebrae extending from the nuchal line of the skull to the sacrum. The term erector spinae refers collectively to a large group of muscles consisting of the multifidus in the lumbar and lower thoracic area; the semispinalis muscles extending from the lumbar, thoracic, and cervical areas; and the longissimus in the lateral lumbar area. The erector spinae is encased in an anterior and a posterior investing fascia that is thickened in the lumbar area as the iliolumbar and thoracolumbar fascia. The muscle bulk is thickest in the upper lumbar and thoracic areas. Superiorly, it is covered by the trapezius muscle from the occiput down to T12 and from approximately T6 to L2 it is covered by the latissimus muscle beneath the trapezius.

Composition  Muscle.
Size  60 cm long × 6 to 8 cm wide.
Origin  Muscles arise segmentally from the sacrum and iliolumbar fascia and the transverse processes of the vertebrae and medial ribs.
Insertion  Muscles insert segmentally into transverse processes of the spine, all the way to the occiput of the skull.
Function  Extension and lateral flexion of the spine.

Arterial Anatomy (Type IV)

Dominant Pedicle  Consists of segmental perforators arising from the posterior intercostal vessels
Regional Source  Aorta.
Length  2 to 3 cm extramuscular.
Diameter  1.5 to 2 mm.
Location  These branches enter the deep medial surface of the muscle between the transverse processes 2 to 3 cm lateral to the spinous processes.

Minor Pedicle  Lateral perforator row
Regional Source  Posterior intercostals arteries.
Length  2 to 3 cm extramuscular.
Diameter  1 to 1.5 mm.
Location  Deep surface of muscle in its midportion.

Venous Anatomy
Closely parallels the arterial anatomy.

Nerve Supply
Motor  Segmental intercostal.
Sensory  Segmental intercostal.
Vascular Anatomy of the Paraspinous Flap

Fig. 7G-2  A, Laser angiogram with indocyanine green of the paraspinous muscles in a patient following explantation of Harrington rods. Both paraspinal muscle masses are shown, indicating medial and lateral perforator rows. The lateral perforators have been exposed after advancement of the medial edge of the muscles toward the midline following longitudinal incision of the paraspinous fascia. B, Segmental blood supply of the paraspinous muscle demonstrated in this latex injected fresh tissue cadaver.
**FLAP HARVEST**

**Design and Markings**
The paraspinous flaps are used bilaterally to close midline defects of the spine. They are accessed through a midline skin incision. The muscles can be marked between 6 to 8 cm on either side of the midline as two longitudinal columns and are usually exposed for at least 30 cm of their length to close a typical spinal wound.

**Patient Positioning**
Patients are always placed in the prone position with appropriate padding to all pressure points.

**GUIDE TO FLAP DISSECTION**
These patients usually have an open midline wound to begin with; this is frequently associated with a healing or completely healed incision extending superiorly and inferiorly down the midline of the spine. The incision is opened longitudinally to achieve a 20 to 30 cm exposure of muscle. Depending on the location of the incision, the skin is undermined and elevated at the level of the deep fascia overlying the paraspinal muscle mass on either side. Undermining is performed for 6 to 8 cm and no further.

In the cervical and thoracic areas, the trapezius and latissimus muscles can be elevated with the skin as a composite myocutaneous flap to preserve cutaneous perforators arising from these muscles for better wound healing. In the lumbar area, these muscles are absent.
and the dissection plane for exposure is subcutaneous. Once the dorsal fascia overlying the paraspinal muscles has been exposed, it is incised 5 to 6 cm from the midline, extending superiorly and inferiorly parallel to the spine. The fascia is fairly thin in the upper and mid-thoracic levels but thickens substantially in the lumbar region. Once the fascia is opened, the longitudinal muscle mass of the paraspinal muscles can be clearly visualized, and gentle digital dissection stripping superiorly and inferiorly around the lateral edge of the muscle provides good mobilization in a relatively bloodless fashion. Blunt dissection can be carried down anteriorly and slightly medially to the lateral perforator row. It is not necessary to specifically visualize the vessels.

Fig. 7G-4  A, Typical upper midline back defect amenable to repair with paraspinal muscle flaps. B, The trapezius and latissimus muscles are elevated with the skin to expose the surface of the paraspinal muscles. C, The muscular fascia is incised and the muscle is bluntly dissected, mobilizing it toward the midline. Here, bilateral flaps have been mobilized and advanced centrally for total muscle coverage under the skin flap advancement and closure.
ARC OF Rotation
The muscles can be rolled medially in an arc of approximately 60 degrees.

Fig. 7G-5  Medial advancement of the paraspinal muscles to reach the midline occurs by freeing of the superficial, lateral, and deep attachments and by muscle rotation centrally. Visualization of the vascular pedicle is not necessary.

FLAP TRANSFER
Like the pages of a book, the muscle is advanced toward the midline, dividing the muscle proximally or distally if needed for advancement.

FLAP INSET
The two paraspinal muscle blocks are sutured together in the midline using interrupted 0 PDS figure-of-eight sutures. These are placed at 1 to 2 cm intervals down the entire length of the closure after a channel drain has been placed between the muscle and the underlying bone and/or hardware. A second layer of continuous 2–0 PDS suture on a CT needle can be used to imbricate and bury the original suture line. This not only provides a watertight seal but also serves to invert the muscle mass deeper into the spinal wound centrally, thereby helping to fill dead space. A second drain is then placed superficial to the spinal repair.

DONOR SITE CLOSURE
If the flaps have been raised in the thoracic or cervical areas, the separated edges of the latissimus or trapezius muscles respectively can be repaired with a running 2–0 PDS suture, providing additional strength to the repair. The skin is then closed using interrupted subcutaneous closure, followed by a running subcuticular closure or staples. If the skin edges are inflamed and are of poor quality, large, widely spaced 1 Prolene sutures can be placed at 5 cm intervals to help relieve tension centrally.
CLINICAL APPLICATIONS
This 37-year-old patient had undergone spinal fusion for severe kyphoscoliosis 20 years earlier. Six months before presenting, she developed progressive erosion of her spinal hardware through the skin of her upper thoracic region. The wound was positive for methicillin-resistant *Staphylococcus aureus* (MRSA). Explantation of the hardware was planned, with closure using bilateral paraspinal flaps.

![Image](image_url)

**Fig. 7G-6**  
A, Dorsal spinal wound of the thoracic region before explantation of hardware. B, Radiograph of spinal hardware. C, Open midline spinal wound after explantation of Harrington rods. D, Elevation of the trapezius muscle cranially and the paraspinal fascia and medial border of latissimus dorsi caudally. E, Lateral paraspinal perforators passing through the paraspinal muscles and entering the medial border of the latissimus dorsi.
Fig. 7G-6  F, The trapezius and latissimus dorsi muscles were elevated to reveal the length of the paraspinal muscles from cervical to lumbar regions. G, Medial traction was placed on the paraspinal muscles after release of the dorsal muscle fascia 5 cm parallel to the midline. H, The paraspinal muscles were closed in the midline. I, The trapezius muscles approximated. J, Final skin closure with drains inserted. (Case supplied by GJ.)
This 70-year-old man had developed erosion of portions of his spinal hardware, which had been inserted for stabilization of pathologic fractures arising from metastatic disease. His back had been irradiated 18 months previously. The protruding bolts were cut down with a side-cutting burr by the neurosurgeons, and closure was performed using bilateral paraspinal muscle flaps. The patient healed primarily without incident. He died 2 years later from metastatic disease to the lungs.

**Fig. 7G-7**  
A, Back wound showing extruding hardware in the lower thoracic region. B, The wound was debrided, with exposure of the hardware in the thoracic spine. C, The wound was closed with bilateral paraspinal muscle flaps, augmented with medialization of the right latissimus dorsi origin. D, The healed wound is seen 3 weeks postoperatively. (Case supplied by GJ.)
This 45-year-old woman developed sepsis and exposure of her spinal fusion hardware 6 weeks after surgery. The wound was debrided and lavaged, but retention of the hardware was seen as critical, because the patient’s spine was not fused, and removal would result in instability and paraplegia. Closure was planned with bilateral paraspinal flaps, with long-term antibiotic coverage. The wound healed without complication, and the patient went on to successful spinal fusion with hardware retention.

**Fig. 7G-8**  
A, The debrided wound is seen after repeated washout procedures by the neurosurgical service. B, Right paraspinal flap mobilized and advanced across the midline. C, The midline was closed with bilateral paraspinal flaps using the keel inversion technique. D, The skin incision was closed. (Case supplied by GJ.)
Pearls and Pitfalls

- To improve skin edge vascularity, it is very helpful to leave the skin attached to the trapezius and latissimus muscles in the cervical and thoracic portions of the wound.
- The dorsal investing fascia must be incised roughly 5 cm parallel to the spine to allow advancement and rotation into the defect. In the lumbar region, multiple fascial incisions closer to the midline may also be necessary to facilitate this movement.
- It is not necessary to visualize the vascular pedicles, but care should be taken to preserve any vessels that happen to be seen during the dissection, since the flap’s blood supply is entirely segmental.
- Given the immense power of these muscles, medial suturing must be undertaken with strong sutures. The use of figure-of-eight sutures helps to distribute tension, preventing tearing of the muscle as the sutures are tightened.
- Submuscular drainage is essential to prevent seroma formation beneath and superficial to the muscle flaps.
- Great care should be taken with drain placement if the dura is exposed when extensive laminectomies have been performed.

EXPERT COMMENTARY

Glyn Jones

Indications
Spinal closure has been plagued in the past by the perceived paucity of available tissue donor sites and the need for extensive undermining when transposing or advancing latissimus flaps. The practice of undermining led to adjacent wound edge necrosis and dehiscence, converting a problematic wound into a serious and potentially life-threatening situation. The advent of a rapid, simple closure technique has literally transformed the surgical landscape in this clinical setting.

Advantages and Limitations
The paraspinal muscle mass presents us with a parallel block of muscles lining the spinal column from occiput to lumbosacral junction. Their convenient proximity to the wound defect and reliable, segmental blood supply make them the near-ideal wound closure option for spinal wounds. Their ease of dissection makes them a remarkably simple choice, with their maximal utility found between the lower cervical and upper lumbar portions of the spine. The muscles become progressively less bulky and less mobile in the lower lumbar sacral area and become less useful as a consequence.

Anatomic Considerations
From the occiput to the lower thoracic region, the trapezius and latissimus dorsi muscles overlie the paraspinal muscles. They should be left attached to the overlying skin to preserve skin blood supply. Based on their thickness and mobility, the paraspinal muscles are most useful between C6 and L3. Blood vessels enter the deep surface of the muscles as medial and lateral rows.
Personal Experience and Insights

Paraspinal muscle flap usage has transformed my approach to treating midline defects of the spine. Even in aggressively debrided or irradiated wounds, there is usually an adequate supply of residual muscle to achieve central wound closure. The flaps are extremely reliable and simple to mobilize, and provide excellent padding even in thin patients.

Recommendations

Planning

For closing upper cervicothoracic defects, the overlying trapezius muscle should be left attached to the skin edge to bolster wound edge blood supply. Centrally, the medial edge of latissimus dorsi can be advanced and closed as a second layer over the underlying paraspinal mass.

Technique

As dissection commences, the trapezius and/or latissimus muscles are identified, and the plane of dissection is started immediately beneath these muscles, exposing the paraspinal mass beneath.

Paraspinal muscle flap turnover is easily accomplished by releasing the overlying fascia longitudinally, approximately 4 or 5 cm parallel to the midline on either side. Gentle, blunt digital dissection frees up the muscles laterally, allowing medial advancement into the midline. This release enables advancement as well as partial turnover of the muscles into the midline defect. If further mobilization is required, it should be achieved by releasing the deeper lateral muscle attachments up to the lateral perforator row. It is rarely necessary to divide perforators in this operation.

Superficial wounds in which the spinous processes are still present are usually closed with a single plication of interrupted figure-of-eight 2-0 PDS sutures placed every 2 to 3 cm down the muscle length required. In deeper wounds it is desirable to imbricate the muscle mass deeper into the wound, like the keel of a sailing ship. This can be accomplished by running a second layer of inverting 2-0 PDS down the midline to invert the original stitch line into the depths of the wound. This maneuver pushes the medial muscle mass deeper into the defect when the spinous processes and posterior elements have been resected or the spinal cord is exposed.

Draining these wounds is vital to success; 15 Fr hubless channel drains are placed between the flaps and the spinal cord or vertebrae, and a second drain is placed between the muscle fascia and the overlying skin. Drains should be left in place until they are producing less than 30 ml per drain per day. It is helpful to spray the bed of the wound with fibrin glue before closure. Drain placement in the presence of exposed cord should be discussed carefully with the neurosurgical team, particularly if dural repair has been performed and a lumbar drain inserted.

These flaps are extraordinarily easy to raise but can be more difficult in the lumbosacral region, where their bulk declines rapidly toward the L5-S1 level. They are also less bulky in the cervical region but are buttressed in this area by the trapezius muscle.

Postoperative Care

Drains are placed between the spine and the muscle, and between the paraspinous muscles and the skin. Given their close proximity to the spinal cord, drains should only be placed to bulb suction rather than to electromechanical wall suction.

Continued
Complications: Avoidance and Treatment
Any patient at risk for pressure necrosis should be placed on a low-air-loss bed. If a CSF leak was noted by the spine surgeon at the time of debridement, it should be repaired and a lumbar drain inserted prophylactically. Under these circumstances, only a subcutaneous drain is inserted by the reconstructive surgeon.

Take-Away Messages
Paraspinal flaps have become the benchmark procedure for spinal wound closure and have relegated latissimus dorsi turnover flaps to a weak second place. Their reliability and ease of use make them a first-choice procedure, even in irradiated spinal wounds with associated tissue atrophy. The use of bilaminar onlay acellular dermal matrices can augment their role as bulk additives to the midline in thin patients.

Bibliography With Key Annotations

Soft tissue defects of the back, particularly those involving the paravertebral tissues, are generally covered with myocutaneous, muscle, or fasciocutaneous flaps. The authors reported the case of a 64-year-old man with a paravertebral malignant fibrous histiocytoma. To ensure adequately radical margins, the ipsilateral trapezius and latissimus dorsi muscles as well as the costal periostium and the spinous processes were resected between T9 and T12. The resulting defect was covered with a pedicled latissimus dorsi flap and an island flap of the paravertebral muscles. Prompted by this case, the authors studied the blood supply of the paravertebral muscles in 10 cadavers. The vasculature was visualized after flushing with colored latex and microsurgical dissection. Another four specimens were subjected to angiography and tomography. In the majority of cases (8 of 10), three perforators emerging from the intercostal arteries were identified. These were found to communicate in a longitudinal and vertical direction. Before piercing the fascia, they ramified in three layers matching the layers of the paravertebral muscles. Since the intercostal arteries were shown to communicate through anastomoses of adequate caliber, the paravertebral muscles appear to be useful candidates for proximally or distally pedicled transposition or island flaps.


A systematic regionalized approach for the reconstruction of acquired thoracic and lumbar midline defects of the back was described. Twenty-three patients with wounds resulting from pressure necrosis, radiation injury, and postoperative wound infection and dehiscence underwent successful reconstruction. The latissimus dorsi, trapezius, gluteus maximus, and paraspinous muscles were used individually or in combination as advancement, rotation, island, unipedicle, turnover, or bipediclle flaps. All flaps were designed so that their vascular pedicles were out of the field of injury. After thorough debridement, large, deep wounds were closed with two layers of muscle, while smaller, more superficial wounds were reconstructed with one layer. The trapezius muscle was used in the high thoracic area for the deep wound layer, and the paraspinous muscle was used for this layer in the thoracic and lumbar regions. Superficial layer and small wounds in the high thoracic area were reconstructed with either the latissimus dorsi or trapezius muscle. Corresponding wounds in the thoracic and lumbar areas were closed with latissimus dorsi muscle alone or in combination with the gluteus maximus muscle. The rationale for systematic regionalized reconstruction of acquired midline back wounds was described.

The authors described “supercharging” a latissimus dorsi muscle flap for coverage of an irradiated nonhealing wound of the lumbar area of the back. Nonhealing wounds of the lower back pose difficult management problems. In the presence of radiation therapy, infection, and foreign materials, nonhealing wounds can have the potential for disastrous outcomes. Exposed bone and prosthetic materials in an irradiated bed were covered by turning a latissimus dorsi muscle flap over its lower paraspinous origin and anastomosing the thoracodorsal artery and vein to the ipsilateral superior gluteal vessels. Postoperatively, the patient’s wound healed without incident, and the muscle flap and skin graft provided a stable and durable reconstruction. Subsequent duplex Doppler imaging demonstrated a significant inflow to the flap from the superior gluteal artery and vein anastomosed to the thoracodorsal artery and vein of the muscle.


An iliac crest bone graft with an intact quadratus lumborum muscle pedicle was devised for the surgical repair of symptomatic pseudarthroses in failed lumbosacral spinal fusions. The graft and pedicle were rotated into a paraspinous bed and internally fixed to the spine. The preliminary results were presented in 12 patients in whom operations were performed under the direction of a single surgeon. Follow-up averaged 39 months (range 8 to 68 months). Eleven patients demonstrated radiologic evidence of union, and nine subjectively reported improvement of symptoms. Five complications occurred in four patients. Two superficial infections quickly resolved with appropriate therapy. One patient had neural foraminal encroachment from an internal fixation device, necessitating its early removal. In a fourth patient, major complications of a deep infection and an incisional hernia were successfully treated. Iliac pedicle grafting is an alternative stabilization procedure for use in a select group of patients with disabling pain and previous failed spinal fusion.


Infected spinal stabilization devices represent a significant reconstructive challenge by threatening spinal stability and increasing the risk of neurologic complications. The authors conducted an anatomic and clinical investigation of posterior midline trunk reconstruction using paraspinous muscle flaps as the primary method of repair. They retrospectively analyzed a series of 25 consecutive patients (mean age 57.2 years; range 32 to 78 years) with complex spinal wounds who underwent reconstruction with paraspinous muscle flaps, at a single university health care system. To help define the versatility of these muscle flaps, they also performed cadaveric dissections with lead oxide injections in 10 specimens, with an emphasis on regional blood supply, flap width, and arc of rotation. From 1994 to 2000, the authors successfully reconstructed complex spinal wounds in 25 patients, using 49 paraspinous muscle flaps as the primary method of reconstruction. Hardware present in 22 patients was replaced or retained in 17 cases. Long-term spinal fusion with preservation of neurologic status was observed in all patients, with no cases of dehiscence or reinfection. Wound complications included a CSF leak, skin necrosis, sinus tracts, and seroma. Mean length of stay was 24 days (range 8 to 57 days). One postoperative death occurred. Paraspinous dissections and injections confirmed a segmental type IV blood supply with medial and lateral perforators, arising from intercostal vessels superiorly and lumbar and sacral vessels inferiorly. Flap width was 8 cm at the sacral base, 5 cm at the level of the inferior scapular angle, and 2.5 cm at the first thoracic vertebra.

A trend in large myelomeningocele defect repair involves soft tissue closure with muscle and fascial flap techniques to provide a durable, protective, and tension-free soft tissue covering. The authors proposed that composite tissue closure yields superior outcomes regardless of defect size. They presented a retrospective review of their 15-year, single-institution experience using this approach. The study included 45 consecutive patients treated using combinations of muscle and fascia flaps for primary closure of a myelomeningocele defect. Lumbosacral fascia closures were used in 18 cases with paraspinous muscle closure and 12 cases without paraspinous closure. Fascial closure with bony pedicle periosteum and gluteal muscle and fascial closure were used in four cases each. Other techniques included latissimus dorsi flaps and combinations of these techniques. Postoperatively, none of our patients experienced a cerebrospinal fluid leak, and only one patient required reoperation for skin flap necrosis. Objective measures show that universal application of flap techniques may lead to better outcomes for soft tissue closure during myelomeningocele repair.


Coverage of midline posterior spine wounds presents a challenge to the reconstructive surgeon, especially when spinal stabilization hardware is present and exposed in the wound. Most commonly, wounds that involve the mid to upper thoracic spine have been covered by latissimus dorsi muscle or myocutaneous flaps. Lower midline wounds, especially in the thoracolumbar region, have needed more complex means of coverage. These have included reversed latissimus dorsi flaps, free flaps, extended intercostal flaps, or fasciocutaneous rotation flaps. The authors used a far simpler and more effective muscle flap: the paraspinous muscle flap. They raised paraspinous muscle flaps bilaterally and were able to cover a number of difficult wounds. The wounds were presented by eight patients with exposed Harrington rods, three patients with cerebrospinal fluid leaks, and one patient with exposed spinous processes. The wounds in five of these patients were in the upper thoracic region, where a latissimus flap was used as an additional layer of muscle coverage. The other seven patients had wounds in the lower midline region below the potential reach of the latissimus dorsi. In the latter patients, the only flaps employed were paraspinous muscle flaps. They had only one failure in all patients, which involved a recurrent CSF leak in which there was no decompression of the cerebrospinal fluid pressure used in the immediate postoperative period to protect the dural repair. In that instance, a leak recurred.


The paraspinous muscle flap is often overlooked for use in cervical wounds; surgeons cite the decreased size and mobility of the muscles in the cervical region. The authors discussed the paraspinous muscle flap technique for reconstruction of cervical spine wounds. An 11-year, single-institution, retrospective chart review was performed on 14 consecutive patients from 1996 to 2007. All patients underwent paraspinous muscle flap surgery to provide soft tissue coverage of the cervical spine after wound healing complications resulting in exposed hardware or bone. Variables of interest included demographics, comorbidities, and postreconstruction wound-healing complications. The overall complication rate after paraspinous muscle flap surgery was low, 2 of 14 (14%) and consisted of 2 minor wound infections. There was no postreconstruction seroma, a well-known complication associated with use of the trapezius muscle flap, which is often thought of as the first-line option for posterior cervical soft tissue reconstruction. The authors concluded that the paraspinous muscle flap is an expedient and reliable solution to complex cervical spine wounds.


The authors presented a study to introduce modifications in paraspinous muscle flap surgery and compare this new variant's ability to salvage infected hardware with the classic technique. Infected posterior spine wounds are a difficult problem for reconstructive surgeons. Hardware retention in infected wounds maintains spinal stability, decreases length of stay, and decreases the wound-healing
complication rate. The authors conducted an 11-year retrospective office and hospital chart review. All patients who underwent paraspinous muscle flap reconstruction for wound infections following spine surgery during this period were included. There were 51 patients in the study, representing the largest reported series to date for this procedure. Twenty-two patients underwent treatment using the modified technique and 29 patients were treated using the classic technique. There was no statistical difference between the two groups in demographics, medical history, or reason for the initial spine surgery. The hardware salvage rate associated with the modified technique was greater than the rate associated with the classic technique (95.4% versus 75.8%). There were fewer postreconstruction wound-healing complications requiring hospital readmission in the modified technique group than in the classic group (13.6% versus 44.8%). Patients in the modified technique group demonstrated a shorter mean length of stay than the patients in the classic group (23.7 days versus 29.7). The authors concluded that the modified paraspinous muscle flap technique is an excellent option for spinal wound reconstruction, preservation of spinal hardware, and local infection control.


With increasingly complex spine surgeries now being performed on a more comorbid patient population, the reconstruction of midline back wounds from these procedures is becoming a frequent dilemma encountered by plastic surgeons. The purpose of this study was to examine the effect of various preoperative risk factors on postoperative wound-healing complications after paraspinous muscle flap reconstruction of midline back defects. An 11-year retrospective office and hospital chart review was conducted. All adult patients who underwent paraspinous muscle flap reconstruction during the study period were included. There were 92 patients in the study, representing the largest reported series to date for the paraspinous muscle flap procedure. Mean follow-up was 120 days. Several wound-healing risk factors were present in this patient population: 72% were malnourished, 41% had hypertension, 37% were obese, 34% had a history of smoking, 32% had diabetes, 16% were on a long-term steroid regimen, 14% had a history of more than two previous spine surgeries, and 9% had a history of radiation to the wound area. Factors significantly associated with postreconstruction wound complications included a history of traumatic spine injury, prereconstruction hardware removal, a history of more than two spine surgeries, hypertension, and lumbar wound location. This patient population had multiple comorbidities, making complex wound healing difficult. Several specific risk factors are associated with an increased rate of postreconstruction wound complications after paraspinous muscle flaps. The paraspinous muscle flap remains an important tool for spinal wound reconstruction in the reconstructive surgeon’s armamentarium.


A prospective clinical study was conducted to evaluate the efficacy of paraspinous muscle flap coverage using a “vest-over-pants” closure in the prevention and treatment of cerebrospinal fluid fistulas in high-risk patients. Previous studies had described paraspinous muscle flaps for the closure of complex spinal wounds, but none had addressed their use for the prevention and treatment of cerebrospinal fluid fistulas. This study evaluated nine consecutive patients who either had refractory cerebrospinal fluid fistulas or were at high risk for CSF leaks after spinal surgery. Bilateral paraspinous muscle flaps were used as primary flaps and were closed using an overlapping vest-over-pants technique in eight of nine cases. The latissimus dorsi and trapezius muscles were recruited as additional muscle flaps for closure of thoracolumbar and high thoracic deficits, respectively. Paraspinous muscle flaps provided immediate wound coverage in seven high-risk patients undergoing spinal surgery and two patients with recurrent CSF fistulas. Postoperative hospitalization averaged 14.4 days. There was no evidence of a cerebrospinal fluid fistula after an average follow-up of 176.7 days. No wound infections occurred. The only complications were a superficial hematoma, which was drained percutaneously on postoperative day 6, and a seroma, which was drained during the follow-up period and eventually resolved.

The authors presented a study to evaluate the vascular anatomy of the paraspinous muscles and reviewed their clinical use as bipedicled flaps in spinal wound closure. Anatomically, through cadaver dissections, lead oxide injections, and radiographic imaging, the blood supply to the paraspinous muscles was determined. Clinically, 29 consecutive patients treated with spinal wounds and exposed bone or hardware were reviewed retrospectively. Of these patients, 19 had delayed primary closure, and 10 were referred to plastic surgery for reconstruction because of the complex nature of their wounds. The cadaver study demonstrated the paraspinous muscles to possess a segmental arterial supply through medial and lateral perforators. Division of the medial perforators allowed medial advancement of the muscles. Lead oxide injection of the lateral perforators demonstrated adequate medial muscle perfusion with ligation of the medial perforators. Ten of the 29 patients (six women, four men, 32 to 62 years of age) underwent reconstruction with paraspinous, latissimus, and trapezius muscle flaps. A higher complication rate was found in wounds closed in delayed primary fashion (13 of 19 patients; 68%) than those reconstructed with muscle flaps (2 of 10 patients; 20%). Follow-up of the patients who underwent muscle flap reconstruction averaged 12 months (range 3 to 27 months). Cadaver muscle injections predicted and clinical cases confirmed that the paraspinous muscles can be raised on lateral perforators and advanced medially to close lumbar spine wounds reliably with fewer complications.
Chapter 8

Upper Extremity

Plastic surgery requires an intimate understanding of the anatomy of the whole body. For hand surgeons and general reconstructive surgeons, the arm is an invaluable donor site for reconstructive flaps; the morbidity associated with the upper extremity is low. Although important for regional applications, arm flaps are of greatest value in distant reconstruction, particularly the head and neck.

Lateral Arm Flap
Brachioradialis Flap
Posterior Interosseous Flap
Radial Forearm Flap
Flexor Carpi Ulnaris Flap
Ulnar Forearm Flap
### ANATOMIC LANDMARKS

| **Landmarks** | Flap occupies the lateral arm from the deltid insertion to the proximal third of the forearm. |
| **Size** | 20 × 14 cm (6 cm for primary closure); bone 10 to 15 cm. |
| **Composition** | Fasciocutaneous, osteocutaneous. |
| **Dominant Pedicle** | Posterior radial collateral artery. |
| **Nerve Supply** | Lower lateral cutaneous nerve of the arm (C5–C6). |
Section 8A

UPPER EXTREMITY

Lateral Arm Flap

CLINICAL APPLICATIONS

Regional Use
- Upper extremity
- Shoulder
- Elbow

Distant Use
- Head and neck
- Upper extremity
- Hand reconstruction
- Lower extremity
ANATOMY OF THE LATERAL ARM FLAP

Fig. 8A-1

Dominant pedicle: Posterior radial collateral artery
ANATOMY

Landmarks  Flap occupies the lateral arm from the deltoid insertion to the proximal third of the forearm.

Composition  Fasciocutaneous, osteocutaneous. Flap is most commonly used for resurfacing. It is possible to harvest a segment of the distal humerus from the supracondylar ridge to the lateral epicondyly.

Size  20 × 14 cm (6 cm for primary closure); bone 10 to 15 cm.

Arterial Anatomy

Dominant Pedicle  *Posterior radial collateral artery*

Regional Source  Profunda brachii artery (brachial artery).

Length  7 cm.

Diameter  2.5 mm.

Location  Posterior radial collateral artery (PRCA) enters the lateral intermuscular septum, passing in between the brachialis muscles anteriorly and the lateral head of the triceps posteriorly. Within the septum, the artery gives off periosteal and muscular branches as well as four or five septocutaneous arterial branches. At the distal end of the spiral groove, the diameter is 2.5 mm.
Venous Anatomy

This flap has two drainage systems: deep and superficial. The deep system consists of the venae comitantes that travel with the PRCA. At the distal end of the spiral groove, their diameter is 2.5 mm. The superficial system drains into the cephalic vein and communicates with the deep system by several small branches. Either system can be used to drain the flap.

Nerve Supply

The lower lateral cutaneous nerve of the arm is a branch of the radial nerve, which perforates the lateral head of the triceps near the deltoid insertion. It then passes anteriorly up to the elbow near the cephalic vein and supplies the skin of the lateral arm above and below the elbow.

Vascular Anatomy of the Lateral Arm Flap

Fig. 8A-2

Dominant pedicle: Posterior radial collateral artery (D)
**FLAP HARVEST**

**Design and Markings**
A line is drawn from the deltoid muscle insertion to the lateral epicondyle that bisects the flap. The superiormost extent of the skin design is at the deltoid insertion, and the flap can extend distally over the lateral epicondyle of the humerus. Primary closure of the donor site is obtainable in flaps 6 cm or less in width, and flaps as large as 20 by 14 cm have been designed.

**Fig. 8A-3** With the patient either standing or supine, a line is drawn from the deltoid insertion to the lateral epicondyle of the humerus. This line represents the central axis of the flap. It also delineates the lateral intermuscular septum and the course of the PRCA.

**Patient Positioning**
The patient is placed in the supine or lateral decubitus position.
GUIDE TO FLAP DISSECTION
The lateral arm flap is first approached posteriorly, and the incision is deepened down to the fascia of the triceps muscle, which is elevated with the flap. The lateral intermuscular septum is exposed, and the branches of the vessel to the triceps are ligated. The posterior branch of the radial collateral artery and the posterior cutaneous nerve of the forearm are then exposed. It is helpful to retract the triceps muscle posteriorly to facilitate dissection.

At the posterior border of the flap the lower lateral cutaneous nerve of the arm is identified, and if desired, it is preserved with the flap. The incision continues anteriorly down through muscular fascia, with elevation toward the intermuscular septum laterally.
The PRCA can then be seen from both sides, and the septum is detached from the humerus from distal to proximal. The anterior branch of the radial collateral artery and the posterior cutaneous nerve of the forearm are divided. Dissection of the pedicle proceeds proximally. Pedicle lengths of 4 to 8 cm can be obtained.

**Fig. 8A-4 B**, The anterior margin of the flap is incised down to and through the deep fascia overlying the brachialis muscle and the brachioradialis muscle. Dissection proceeds in the subfascial plane posteriorly.

The lateral intermuscular septum is then dissected from the humerus in a distal to proximal direction.
FLAP VARIANTS

- Extended lateral arm flap
- Reverse flap
- Fascial flap
- Osteocutaneous flap
- Vascularized nerve graft

Extended Lateral Arm Flap
The skin design can be moved distally to capture the thinner tissues below the elbow that extend over the proximal third of the arm. This has the added advantage of lengthening the vascular pedicle. Dissection distally is in the subfascial plane. Once the area of the lateral epicondyle is passed, the dissection proceeds as described above.

Reverse Flap
The radial collateral artery anastomoses with the radial recurrent artery and vein posterior to the lateral epicondyle. A reverse flap may be elevated on this distal vascular anastomosis for coverage of elbow defects. The standard design is used, and the initial dissection is similar to the standard flap. Once the septum is isolated from anterior and posterior, the direction of dissection is proximal to distal. The anastomotic vessels are located in the epicondylar area in the subcutaneous tissues near the periosteum. No attempt is made to see these vessels; rather, all subcutaneous tissues and periosteum are kept en bloc as a pedicle for the flap. The flap is then rotated directly into the defect or through a generous subcutaneous tunnel. A width of 6 cm or less will allow primary closure of the donor site.

![Extended lateral arm flap design](image)
Fascial Flap
The fascial flap can be designed to be 10 to 14 cm wide and 14 to 10 cm long in cases in which vascularized fascia is required. After elevating skin flaps at the subcutaneous level over the desired fascia, the dissection proceeds as described previously. In such cases its surface may be grafted at the recipient site, if required.

Osteocutaneous Flap
The osseus segment from the posterior lateral aspect of the humerus can be included with the flap. The blood supply to the bone is from the periosteum and requires a small segment of attached triceps and brachioradialis muscles for vascularization. A flap 10 to 15 cm long and 1 cm wide can be harvested.

Fig. 8A-6  A, An osseous segment may be included with the cutaneous flap. An incision is made through a portion of the lateral head of the triceps muscle adjacent to the lateral intermuscular septum. A posterior osteotomy is then performed. B, With the flap retracted posteriorly, an incision is made through a portion of the brachialis and brachioradialis muscles adjacent to the lateral intermuscular septum. The anterior osteotomy is then performed. Care must be taken to avoid injury to the radial nerve, which must first be identified and retracted.

Vascularized Nerve Graft
A 10 cm segment of the posterior cutaneous nerve of the forearm can be harvested as a vascularized nerve graft, nurtured by the PRCA and its vena comitans.
ARC OF ROTATION

Standard Flap
The standard flap design is based on the proximal PRCA pedicle. It can reach the posterior shoulder and axilla.

Extended Flap
Extension of the flap design distally over the proximal third of the forearm will extend the reach of the standard flap by that amount.

Reverse Flap
The reverse lateral arm flap easily reaches the lateral elbow and antecubital fossa.
FLAP TRANSFER

Standard, Extended, and Reverse Flaps
The flap is transferred by transposition to the neighboring defect. It is most commonly done by direct extension connecting the donor and recipient sites. Alternatively, the flap may be passed through a subcutaneous tunnel.

Free Flap
When the lateral arm flap is transferred as a free flap, microsurgical principles apply.

FLAP INSET
Care must be taken to insert the flap without tension and without kinking or torsion of the vascular pedicle when it is passed through a subcutaneous tunnel. Adequate room must be allowed for flap passage and to accommodate postoperative swelling. In a free tissue transfer, undue tension on the microvascular anastomosis must be avoided.

DONOR SITE CLOSURE

All Flaps
Primary closure can be obtained when the width of the flap is 6 cm or less; subcutaneous undermining may be necessary to accomplish this. Larger flap designs may necessitate skin grafting to close the donor site.
CLINICAL APPLICATIONS
This 40-year-old man had a recurrent pleomorphic adenoma of the parotid gland; he had undergone previous excision and irradiation.

Fig. 8A-9  A, The defect is seen after wide excision of the patient’s recurrent adenoma; the excision included sacrifice of the facial nerve. B, Flap design. The flap width was based on the defect size and the desire to close the donor primarily. C, The flap is elevated and ready for transfer.
Fig. 8A-9  D, After flap inset with anastomosis to the facial artery and vein. E, Two months postoperatively, the patient is seen in frontal view with good early contour. F, Lateral view. The color match on the face is not ideal. Without postoperative irradiation, hair growth may be an issue in some patients, requiring ancillary laser treatment. G, Donor site. The resulting scar can be unsightly but is preferable to a skin-grafted donor site. (Case supplied by MRZ.)
This patient had multiple open metacarpal fractures, with extensor tendon and dorsal skin loss of the hand. Osteosynthesis with plates and extensor tendon repair with grafts required thin, well-vascularized coverage with fascia to facilitate tendon glide. The lateral arm flap fulfilled these criteria.

![Fig. 8A-10](image)

**Fig. 8A-10**  
A, The patient's dorsal hand avulsion injury resulted in skin and extensor tendon loss, with multiple open metacarpal fractures. B, Open reduction and internal fixation of metacarpal fractures were performed after the wound was debrided. C, A template of the skin deficit was designed with proper orientation of the vascular pedicle. D, A line was drawn from the deltoid insertion to the lateral epicondyle that corresponded to the lateral intermuscular septum. The predesigned template of the deficit was centered and marked over the main axis of the flap along the intermuscular septum. E, Flap dissection started posteriorly, over the triceps brachii muscle and tendon. F, An easy plane of dissection was carried out between the triceps brachii muscle epimysium and the lateral arm flap deep fascia.
Upper Extremity • 8A: Lateral Arm Flap

Fig. 8A-10  G, The pedicle was visualized along its entire course within the lateral intermuscular septum after posterior flap dissection. H, Anterior dissection of the flap was performed, and the pedicle was identified within the lateral intermuscular septum. The posterior cutaneous nerve of the forearm (arrow) can be seen entering the flap and was preserved. I, The pedicle was separated from its humeral attachment within the lateral intermuscular septum. J, The lateral arm flap was harvested. K, The flap was inset into the dorsal hand wound after extensor tendon reconstruction. Tendon grafts were passed through the subcutaneous layer of the flap. L and M, Range of motion 6 months postoperatively. N, The patient had hypoesthesia in the proximal lateral aspect of the forearm from transection of the posterior cutaneous nerve of the forearm. (Case courtesy Luis R. Scheker, MD.)
This 19-year-old woman had severe crush injuries to both hands and was managed elsewhere.

**Fig. 8A-11**  
A, Preoperative image of patient's injuries. B, The first webspace was released, with pinning of the first metacarpal. C, A lateral arm free flap was designed; note the sterile tourniquet. D, The flap after dissection; the pedicle is located to the left. The arrow points to the radial nerve. E, The immediate postoperative result is shown. F and G, Twelve years postoperatively, her release and motion are demonstrated. (Case courtesy William C. Pederson, MD.)
This 35-year-old patient presented after burns and contracture of the palm.

Fig. 8A-12  A and B, The patient's burn injuries are seen preoperatively. C, The palm after release of the contracture. Anastomoses were performed to the radial artery and cephalic vein in the anatomic snuffbox on the dorsal wrist. D and E, Intraoperative views of the release. F and G, The results are shown at 6 months postoperatively. (Case courtesy William C. Pederson, MD.)
This paraplegic patient had a chronic elbow wound. A failed primary closure and skin grafting had been done.

Fig. 8A-13  A, Preoperative view. B, Markings for distally pedicled lateral arm flap for elbow defect. There was a strong Doppler arterial signal in the distal vessel at the level of the lateral epicondyle. C, The flap after dissection. The distal pedicle is shown to the left, with a microvascular clamp on the proximal pedicle to evaluate flow to the flap through the retrograde circulation. D, The flap after inset. The donor site was closed primarily. E, Healing of the flap at 4 months postoperatively. (Case courtesy William C. Pederson, MD.)
PEARLS AND PITFALLS

- The lateral arm flap is useful in the head and neck when both skin and segmental bone are required for reconstruction.
- The flap can be used as a flow-through flap, especially in hand reconstruction, where the PRCA can be used to revascularize the hand or digits.
- This flap may be too bulky for use in an obese patient. In such cases a fascial flap can be taken and skin grafted.
- Division of the posterior cutaneous nerve of the forearm results in anesthesia of the superior lateral forearm.
- The lateral arm flap is advantageous for hand reconstruction because it does not eliminate a major arterial supply to the hand, as do radial and ulnar based flaps. Thus the lateral arm flap can be raised from the same extremity that is being reconstructed, limiting morbidity to one extremity.
- Anatomic variation in the lateral arm flap is minimal.
- This flap may be disadvantageous in hirsute individuals, if hair-bearing skin is not desirable in the reconstruction.

EXPERT COMMENTARY

William C. Pederson

Indications
The lateral arm flap is indicated for smaller wounds of the hand (and body) where a reliable small free flap is needed. I think it is ideal for placement in the first webspace after injury or release of contracture. The flap fits this space perfectly, and although the pedicle is relatively short, recipient vessels are available in the anatomic snuffbox. The flap has applications for coverage and fill in small defects of the head and neck and lower extremity. It may be used as a pedicled flap, both proximally and distally based.

Advantages and Limitations
The flap supplies a free flap with a relatively easy dissection, reliable vascular pedicle, and reasonable donor site. Flaps up to about 7 cm in width can usually be closed primarily. The primary limitation of the flap is that its size is limited. The pedicle is relatively short and the artery is relatively small, but neither is a problem, as long as the flap anatomy and limitations are understood.

Anatomic Considerations
The length of the pedicle is limited by its curving around the humerus, but the vascular pedicle often becomes entwined around the radial nerve in my experience, and this truly limits the length (primarily of the vein) that can be harvested. Distally based flaps may be unreliable because the size and presence of the distal vessel are variable. The presence of this vessel, determined by Doppler examination, will usually obviate this problem.
Personal Experience and Insights
I find this flap very good for coverage of the hand in injuries and prefer the ipsilateral flap. It is my flap of choice for soft tissue fill after release of first webspace contractures. It is shaped like a wedge, and with release of the first webspace, a wedge-shaped defect is created. The radial artery and cephalic vein provide easy vascular access for this flap on the dorsal hand or first webspace. It is not really a flat flap, but when placed on the dorsal hand, it will usually require later thinning and inset to avoid bulkiness. It offers an excellent choice for fill in small soft tissue defects of the head and neck, such as temporal wasting after a temporal craniotomy.

Recommendations

Planning
I prefer to use Doppler ultrasonography to delineate the main pedicle before elevation. A template of the defect can be helpful in designing the flap.

Technique
The center line of the flap is marked and outlined before placing the tourniquet. A sterile tourniquet is used so that it can be removed if needed to dissect the proximalmost portion of the pedicle. The surgeon must be aware of the radial nerve coursing anteriorly into the brachialis muscle at the more proximal portion of the pedicle dissection. At least a dermal closure of the donor site should be performed before placing the flap on the recipient site. If this is not done, swelling may make it difficult to close the donor site later.

Postoperative Care
I often place the patient in a posterior elbow splint if the donor site closure is a bit tight.

Complications
Most complications of this flap are related to microsurgery. The radial nerve can be injured in the dissection, but with care, this is unusual. Hard retractors should not be placed on the anterior muscles during the dissection (the radial nerve runs anteriorly in the brachialis muscle after coming around the humerus). I had one patient develop symptoms of radial nerve compression and compartment syndrome on the first postoperative night when the donor site was closed primarily (and it was too tight). The closure must be carefully evaluated and a skin graft placed if it appears to be too tight.

Take-Away Message
This flap is ideal for the management of smaller traumatic wounds of the hand. It is possibly the best option for reconstruction of the first webspace after contracture release.
### Bibliography With Key Annotations


Lateral arm flaps are versatile for use in upper extremity moderate-sized defects, with little morbidity and acceptable cosmesis. In this paper the conditions were outlined in a series of 74 lateral arm flaps performed on 72 patients, and the results were discussed. Five patients were treated emergently, 12 were operated within the first 72 hours of injury, and 57 patients were treated electively. Skin defects were between 6 by 4 cm and 20 by 9 cm. Five (7%) flaps were lost as a result of venous thrombosis; three had sustained a high-voltage electric burn. Two other patients that were treated for a high-voltage electric burn had a successful revision of the anastomosis site in the early postoperative period. One flap was abandoned because of a very thin pedicle and the patient’s obesity. A higher failure rate is encountered most frequently with the cases of high-voltage electric burn. To deal with this problem, a modified approach such as an extended approach and/or including the forearm skin to the flap is recommended during the flap harvest. For a longer pedicle to be anastomosed more proximally, perforator flaps with longer pedicles may be used as an alternative.


The distal lateral arm flap was used to reconstruct six extensive defects of the digits: two degloving injuries of the thumb and four major skin losses of the fingers. Two adjacent fingers were involved in one patient. Flap size ranged from 3 by 7 cm to 9 by 14 cm. Four flaps were reinnervated using the posterior cutaneous nerve of the forearm. All flaps survived, although one showed marginal necrosis. Average follow-up was 53.4 months. Thumb opposition scored 5 according to the Kapandji index; finger range of motion averaged 50.75%; pinch strength 72.5%. Protective sensation with touch localization was restored. Patient satisfaction for resurfaced digits averaged 8.9 on a 10-point visual analog scale. All donor sites resulted in a painless scar with good patient satisfaction. The authors concluded that the distal lateral arm flap offers a thin, pliable skin ideal for digit reconstruction, with a low rate of donor site morbidity, and it can be considered when toe-to-hand flap transfer is not advisable or is refused by the patient.


The reconstruction of extended tumor-related defects in different anatomic regions requires a versatile and reliable flap. For many surgeons, the lateral arm flap has become the technique of choice in the reconstruction of small- to medium-sized defects. The aim of this study was to analyze the reconstructive potential of the lateral arm flap after cancer ablation in various indications. Between 1998 and 2006, 14 patients underwent reconstruction with differently composed and designed lateral arm flaps. Complete coverage of all defects was achieved with a single surgical procedure. With a flap survival rate of 100% in this series, excellent long-term results, and high patient satisfaction, combined with low donor site morbidity, the authors recommended the use of the lateral arm flap in tumor patients.


For many surgeons, the potential to reconstruct skin, fascia, tendon, or bone in a single-stage procedure has made the lateral arm flap the technique of choice for reconstruction of complex defects. The aim of this study was to examine more closely how the humeral bone is supplied by the posterior collateral radial artery. To this end, the authors dissected 30 cadaver arms to determine the vascular relationship of the lateral arm flap to the humerus. They examined the number of directly supplying vessels and the height to the lateral epicondyle of the humerus. The reconstructive potential of the osteocutaneous flap in different indications was analyzed in a series of five clinical cases. In all dissected extremities, they found one or two branches of the posterior collateral artery directly and constantly supplying the bone between 2 and 7 cm proximal to the lateral epicondyle. In five cases, combined defects, including bone, were successfully reconstructed with lateral arm flaps, including vascularized bone.

The authors presented a new approach to reconstruction of the Achilles tendon and overlying soft tissue. A fascia lata graft was used to reconstruct the tendon, enwrapped by the fascia that is included in a fasciocutaneous lateral arm flap. Five patients were treated with this technique—three of them after surgical Achilles tendon repair, rupture, and consecutive infection; one after a full-thickness burn with loss of the tendon; and one with a history of ochronosis and necrosis of the whole tendon and overlying soft tissue. There were no anastomotic complications, and all flaps healed primarily. Functional evaluation with the Cybex II dynamometer was done at least 49 months after reconstruction. A good functional and cosmetic result was obtained in all patients, and donor site morbidity was acceptable. These results are well within the results of other surgical treatment options reported in the literature.


The forearm part of the extended lateral arm flap may be separately raised on the distalmost septocutaneous perforator of the posterior collateral radial artery. This truly distal lateral arm flap shares most of the advantages of the radial forearm flap and is associated with less donor site morbidity. From April 2000 to March 2004, the authors used 30 such flaps as the fasciocutaneous free flap of choice, mostly for reconstructions in the head and neck region. The eventful postoperative course observed in 5 of these flaps motivated them to evaluate the rationale and risk factors of this procedure. They prospectively analyzed the influence on the incidence of partial or complete flap loss of 19 patient-related or procedure-related characteristics that may have been risk factors. None of these factors was found to be of statistical significance. They found the distal lateral arm flap to have a less robust vascular anatomy than the radial forearm flap, resulting in the need for advanced surgical expertise to raise and handle it. As they recognized that the difficulty of this flap was associated predominantly with the anatomy of its vascular pedicle, they stated that they now take a more liberal stand toward the possibility of intraoperative conversion to the use of a radial forearm flap.


Swallowing, speech, and morbidity were assessed postoperatively in 25 patients, 18 of whom had had intraoral defects reconstructed by lateral upper arm free flaps (LUFF) and 7 by radial forearm free flaps (RFFF). Videofluoroscopy was used to assess swallowing, the Freiburger audiometric test to assess speech, and measurement of arm circumference to assess donor site morbidity. A questionnaire was used to subjectively evaluate swallowing, speech, and donor site morbidity. The degree of impairment in swallowing depended on the site of resection. Anterior and posterior resections affected swallowing more than lateral resections. Anterior resection and the use of LUFFs reduced intelligibility. There was no significant difference in impairment between LUFF and RFFF. The authors concluded that the LUFFs are superior to RFFFs because they can be closed primary and the incidence of donor site morbidity is slight.


Soft tissue injuries with associated bone defects are difficult to manage and often require prolonged treatment with repeated interventions. Frequently a free flap is applied as a first step, and bone grafting is carried out in a second procedure. Ideally, these two procedures are combined in one operation, using a soft tissue flap with an attached vascularized bone fragment. The lateral arm flap can provide such an osteoseptocutaneous flap and has been used clinically with success; however, the vascular anatomy of the flap, especially the humeral fragment, has not been described in detail previously, and there is broad disagreement concerning its innervation. In this study, the arteries and nerves of 24 fresh cadaver arms were dissected after injection of colored latex. The levels of origin of the periosteal arteries of the
humerus were also documented. The lateral arm flap has a consistent arterial supply from three septocutaneous perforating branches that are arranged in a predictable pattern. The lateral supracondylar ridge of the humerus is vascularized by direct branches of the posterior branch of the radial collateral artery and by arteries that arise from muscular branches supplying adjacent muscles. The innervation of the lateral arm flap is by the inferior lateral cutaneous nerve of the arm.


The authors described the advantages of the free chimeric lateral arm flap for repair of orocutaneous fistulas/osteoradionecrosis in oromandibular cancers. These benefits include (1) proper thickness of the flap for soft tissue reconstruction in the head and neck lesions, (2) use of the minor flap to reconstruct the intraoral lesion instead of scarifying the local tissue as a local flap, (3) relatively small caliber and length of the pedicle of the minor flap that is well suited for the fistula tract, (4) the minor flap tunnels through the fistula tract, with less damage to surrounding tissue, (5) a composite flap in which part of the triceps muscle, the humeral bone, or both can be included, and (6) minimal donor site morbidity.


The authors investigated the distribution of constant cutaneous perforators in the upper arm. A total of 20 amputated upper arms of 10 fresh Korean cadavers were used for the study. Red latex was injected into the axillary arteries of 10 specimens and lead oxide-gelatin mixture (radiopaque material) in the other 10. The cutaneous perforators were then identified by dissection and radiography. The upper arm had several perforating arteries (range 5.7 to 6.3) in the subfascial plane, but only four fasciocutaneous perforators were constant: one in the medial intermuscular septum and three in the lateral intermuscular septum. The constant medial perforators were included in a circle of 2.89 cm in diameter, the center of which was 8.9 cm above and 1.2 cm medial to the medial epicondyle. The mean length and diameter of the extended pedicle of the medial perforator was 2.78 cm and 0.94 mm, respectively. The lowermost constant lateral perforators were included in a circle of 2.44 cm in diameter, the center of which was 16.8 cm above and 0.5 cm medial to the lateral epicondyle. The mean length and diameter of the extended pedicle of the lateral perforator was 2.88 cm and 0.84 mm, respectively. A flap based on the perforator of the medial intermuscular septum is not as simple as with the lateral intermuscular perforator, but direct closure of the donor site is more favorable.

The authors concluded that it is safe to design a free skin flap with knowledge of its dominant perforator.


Ideally, reconstruction of lower extremity soft tissue defects includes not only an aesthetically pleasing three-dimensional shape and solid anchoring to the underlying structures to resist shear forces, but should also address the restoration of sensation. The authors presented a prospective study on defect reconstruction of the lower leg and ankle to evaluate the role of sensate free fasciocutaneous lateral arm flap and the impact of sensory nerve reconstruction. Thirty patients were allocated randomly to the study group (n = 15) that obtained end-to-side sensate coaptation using the lower lateral cutaneous brachial nerve to the tibial nerve using the epineural window technique, or to the control group reconstructed without nerve coaptation. At 1-year follow-up the patients were evaluated for pain sensation, thermal sensibility, static and moving two-point discrimination, and Semmes-Weinstein monofilament tests. Data from both groups were compared and statistically analyzed with the Mann-Whitney U test and the Fisher exact test. Flaps of the study group reached a static and moving two-point discrimination and Semmes-Weinstein monofilament results nearly equal to the contralateral leg area, and significantly better than flaps of the control group. Donor damage morbidity of the tibial nerve did not occur. The authors recommended that resensation be carried out by end-to-side neurorrhaphy to the tibial nerve because of the superior restoration of sensibility.

The free lateral arm flap may be harvested as a fascial, fasciocutaneous, or osteofasciocutaneous flap. Simultaneous flap elevation with preparation of the recipient site, easy dissection, minimal donor-site morbidity, and a constant vascular anatomy with long pedicle are advantages of the flap. In this study, the authors presented 18 patients operated on between January 2002 and August 2003 in whom 18 free lateral arm flaps were used. There were 4 women and 14 men; the mean patient age was 40 years. Thirteen fasciocutaneous, 3 fascial, and 2 osteofasciocutaneous flaps were used. Flaps were employed for the reconstruction of the lower extremity in 5 patients, upper extremity in 9 patients, and head and neck in 4 patients. Thirteen flaps were elevated under axillary block and 5 flaps under general anesthesia. Aspirin, dipyridamole, dextran, and chlorpromazine were administered postoperatively. Venous insufficiency developed in two lower-extremity reconstructions on postoperative day 1. Venous thromboses were detected, anastomoses were redone, and flaps healed uneventfully. No postoperative complications were observed in the other patients. The free lateral arm flap may be used in various anatomic defects with various indications. It may be elevated under axillary block for extremity reconstructions.


A composite defect of the posterior aspect of the heel, including the Achilles tendon, is usually very difficult to reconstruct because of the problems of controlling infection, resurfacing the deficient skin defect, and restoring plantar flexion. With the latest advances in microsurgery, several free composite flaps have been used to reconstruct the defect in the Achilles tendon region to achieve stable and functional soft tissue coverage. The authors reported such a single-stage reconstruction of a complex Achilles wound using the modified neurosensory lateral arm free flap, including the triceps tendon strip and the posterior cutaneous nerve. Their rolled-up triceps tendon strip method was presented for the one-stage reconstruction of the Achilles tendon and soft tissue defect, providing good contour, strong tension, and protective sensation. The follow-up has shown a satisfactory outcome.


The patient who needs a flap for a deficit of the foot or ankle soft tissues is any patient who has a break in the integument. Although skin grafts often will suffice, if there is a full-thickness loss, particularly over the plantar bony prominence such as the heel or metatarsal, one should strongly consider flaps. In the author’s practice, the flap procedure most commonly performed for the metatarsal region is the V-Y advancement; for the hindfoot, free tissue transfer; and for the Achilles region, a sural flap. If a lesion is small and the vascular inflow is good, the author uses free tissue transfer of a thin skin flap, such as a lateral arm flap or a radial forearm flap. For the dorsum of the foot, particularly when there is osteomyelitis or a lesion, or a lateral sidewall lesion, he uses a muscle flap. The calcaneus is best served by one of many muscle flaps, such as the gatilis.


Lateral skull base defects following tumor ablation are ideally reconstructed with microvascular free tissue transfer. Although the rectus abdominis free flap is the workhorse in skull base reconstruction, it has a number of drawbacks. Anecdotal reports have indicated that fasciocutaneous free flaps may be useful alternatives in selected cases. Patients undergoing lateral arm (4 cases) or anterolateral thigh (8 cases) fasciocutaneous free flap reconstruction of lateral skull base defects between 1999 and 2005 were therefore reviewed. Twelve consecutive patients (4 males, 8 females) with a mean age of 63 years (range 39 to 74) underwent such reconstruction following resection of lateral (11 cases) and anterolateral (1 case) skull base lesions. Eight patients had squamous cell carcinoma, 3 had infection or osteoradionecrosis, and 1 had adenoid cystic carcinoma. The duration of surgery (from induction of anesthesia to exit from the operating room) averaged 14.5 hours (range 10 to 19.5 hours). All donor sites were closed directly. All the flap transfers were successful, with minimal reconstructive and donor
site morbidity. During the follow-up period (average 18 months; range 2 to 48 months), 2 patients died of metastatic disease, and 2 died of other unrelated causes. The remaining 8 patients were alive and disease free. The authors concluded that lateral arm and anterolateral thigh fasciocutaneous free flaps should be considered as viable reconstructive options for lateral skull base ablative defects.


The authors presented a study of their experience with 210 free lateral arm flaps used to repair head and neck oncologic defects over an 8-year period. Patients' ages ranged from 4 to 83 years (average 49.7 years); 141 were male and 66 female. Three patients received two consecutive flaps each. They were used to reconstruct the tongue, 53 cases; retromolar trigone, 42 cases; soft/hard palate, 34 cases; skin/facial contour, 19 cases; hypopharynx, 17 cases; buccal mucosa, 12 cases; lips, 5 cases. Flap cutaneous dimensions ranged from 4 by 2 cm to 17 by 8 cm. The flap was composed of skin and fascia, 18 cases; sensate (neurovascular) skin, 6 cases; subcutaneous fat tissue, 5 cases; skin and vascularized nerve graft, 3 cases; and skin and partial triceps muscle, 3 cases. Nerve coaptations were performed for all lip reconstructions. Nine flaps did not survive (success rate 95.2%). Severe postoperative clinical complications preceded flap failure and death in 2 cases. All but 6 donor sites were closed primarily. Complications related to the donor site were paresthesia of the forearm, 210 cases; dog ear, 16 cases; hypertrophic scar, 14 cases; weakness, 9 cases; hematoma, 6 cases; seroma, 3 cases; dehiscence, 1 case. Radial nerve injury was not observed in this series. The authors concluded that the lateral arm flap can be considered safe and versatile for most soft tissue head and neck microsurgical reconstructions. The possibility of sensory recovery through neural anastomoses and low donor site morbidity enhances its efficiency.


Complex open posterior elbow injuries pose three principal challenges to the reconstructive surgeon. First, the surgeon must provide stable soft-tissue closure over the joint/skeletal reconstruction. Second, the coverage must be thin and supple and promote the free gliding of the underlying structures. Finally, secondary and tertiary procedures must be anticipated beneath the flap, because a stiff, scarred, and adherent flap will only compromise these procedures. The results of 10 consecutive fasciocutaneous transposition lateral arm flaps for coverage of posterior elbow wounds were reported. This flap provides coverage that is thin and supple and that allows subsequent elevation for secondary procedures. Functionally, these flaps allowed for the development of an average an of motion of 20 to 114 degrees and an average pronation-supination motion of 119 degrees.


The reconstruction of large soft tissue defects at the elbow is hard to achieve by conventional techniques and is complicated by the difficulty of transferring sufficient tissue with adequate elasticity and sensate skin. Surgical treatment should permit early mobilization to avoid permanent functional impairment. Clinical experience with the distal pedicled reversed upper arm flap in 10 patients with large elbow defects is presented (7 men, 3 women; age 40 to 70 years). The patient sample included 6 patients with chronic ulcer, 2 with tissue defects resulting from excision of a histiocytoma, and 1 patient with burn contracture. In the 2 cases of histiocytoma, defect closure of the elbow's ulnar area was achieved by using a recurrent medial upper arm flap. In the 8 other patients a flap from the lateral upper arm was used, with a flap rotation of 180 degrees. Average wound size ranged from 4 to 10 cm, average wound area from 30 to 80 cm². Flap dimensions ranged from 15 by 8 cm for the lateral upper arm flap to 29 by 8 cm for the medial upper arm flap. The inferior posterior radial and ulnar collateral arteries are the major nutrient vessels of the reversed lateral and medial upper arm flaps. Perforating vessels were identified preoperatively using color Doppler ultrasonography. Flap failure did not occur. Secondary wound closure became necessary because of initial wound-healing difficulties in 1 patient.
The mean operative time was 1.5 hours, and the mean follow-up was 12 months. Good defect coverage with tension-free wound closure was achieved in all cases. Stable defect coverage led to long-term wound stability without any restriction of elbow movement. The authors concluded that lateral and medial upper arm flaps represent a safe and reliable surgical treatment option for large elbow defects. The surgical technique is comparatively simple and quick.


Perforator flaps are frequently used for defect coverage for the whole body. There are strong indications for the use of perforator flaps in the upper extremity. This article demonstrated the possibilities for defect coverage with perforator flaps as well as their anatomic and technical considerations. Lateral arm, posterior interosseous artery, ulnar artery, radial artery perforator flaps, and intrinsic hand flaps were described.


If they are not managed with proper treatment and rehabilitation, full-thickness burns involving the cubital fossa can result in severe contractures that may impair upper extremity functions. Later release of these contractures discloses a large soft tissue defect that should be replaced. The authors used reverse lateral arm flaps for coverage of the cubital fossa in 11 selected cases of antecubital contracture. Ten flaps survived totally; there was distal partial necrosis in 1 flap, which was later treated by skin grafting. The authors reported considerable functional improvement in all cases. Although fasciocutaneous flaps offer the advantage of using regional tissue in a single stage, few versatile local flaps relying on the vascular anatomy around the elbow joint are available for cubital fossa coverage. Because it is a rapid, easy, and one-stage procedure with no necessities for sacrifice of a major artery or muscle and for a long-term immobilization of the involved joints, the reverse lateral arm flap appears to be advantageous in comparison with other options for coverage of the cubital fossa defects after the release of antecubital contractures.


The long-term results of hand defects after one-stage reconstruction with lateral arm flap were retrospectively analyzed in a large series. Between 1990 and 2004, 118 traumatic hand defects were reconstructed using lateral arm fasciocutaneous flap (104), lateral arm fascial flap (6), and composite lateral arm flap (8). There were 22 females and 96 males, with an average age of 32.5 ± 13.3 years. Mean follow-up was 17 ± 6.2 months. The overall success rate was 97.5%. The cosmetic outcomes were satisfactory and only 16.1% of the patients required debulking. The functional recovery of the hand contractures secondary to crush injury were generally associated with poor results. In the composite flap group, reconstruction of the extensor tendons with triceps tendon yielded limitation in tendon excursion and poor functional results. However, complete bone healing without complication was uniformly detected in all cases. Lateral arm fasciocutaneous flap endured secondary interventions well, and no complications regarding wound healing were encountered.


Long-term outcomes of foot reconstruction with free lateral arm fasciocutaneous flaps were retrospectively analyzed in 50 patients: 38 males and 12 females, ranging in age from 7 to 73 years (mean 43.5 years). Indications for surgery included trauma (32 patients), diabetes mellitus (7 patients), burns (7 patients), chronic ulcers (3 patients), and tumor (1 patient). The locations of defects were the dorsum (21), ankle (12), medial (6), lateral (6), posterior heel (2), and distal sole (3). Concomitant bone injury occurred in 5 cases, and the weight-bearing surface of the foot was involved in 5 patients. Defects ranged from 27 to 76 cm² (mean 36.4 cm²). Successful reconstructions were accomplished in 46 cases (92%). Flap complications included total flap loss and below-knee amputation (1) and partial flap loss (3); 75% of these patients had diabetes as a comorbid factor, and 25% had a concomitant
bone injury. Six patients with dorsum defects required debulking of the flap (11.1%). None of the patients required modified shoes. In the majority of cases, flaps provided stable coverage and a gain in protective deep-pressure sensation. In long-term follow-up (up to 4 years), patients regained their ambulation, free of pain. Even in weight-bearing areas, none of the patients developed ulceration or skin breakdown. Free lateral arm flaps provided excellent durability, with solid bony union and successful restoration of the contour of the foot in moderate-sized foot defects.


Complex defects of the forearm often require microvascular reconstruction with osteocutaneous free flaps to salvage the limb. In this review, we report our experience with the use of the free osteocutaneous lateral arm flap to reconstruct such defects in four patients. Three male patients with osseous defects of the ulna and one defect of the radius with associated soft tissue defects were treated with a free osteocutaneous lateral arm flap. The indications for the procedure included three cases of posttraumatic osteitis and one bone defect with soft tissue defects after trauma. The authors evaluated postoperative results by evaluating the range of motion, pain, strength, and score on the disabilities of the arm, shoulder, and hand questionnaire. Donor site morbidity was also documented. The average length of segmental bone defects was 5.75 cm. The average dimension of the skin paddle was 99.5 cm. The average follow-up was 43.3 months. All bone flaps healed without nonunion; the fasciocutaneous flaps healed without complications. No problems related to microanastomoses were found. Functional results were very satisfactory; disabilities of the arm, shoulder, and hand questionnaire scores showed a median of 5.8 (0 to 10.8). All patients had returned to their preinjury occupations.


The lateral arm flap is a popular flap for hand resurfacing. Despite its many advantages, it is limited by the available width of the flap. The authors described the application of this long and narrow flap in a turn-around manner, greatly increasing its versatility while achieving primary closure of the donor site. The lateral arm flap was designed with extension onto the forearm (extended lateral arm flap) and harvested in the usual manner. During inset, the distal segment of the flap was brought through a 180 degree U-turn to lie adjacent to the proximal segment. They analyzed the outcomes of 31 turn-around lateral arm flaps performed between 1988 and 2008. All flaps healed well without any vascular compromise. Reconstruction of defects with a variety of configurations was performed with a maximum flap size of 144 cm. Four patients required split skin grafting to the forearm. Primary closure of the lateral arm donor site was achieved in all patients. The authors noted the ease, reliability, and versatility of this simple modification in extending the usefulness of the lateral arm flap in hand reconstruction.
ANATOMIC LANDMARKS

Landmarks  Lies on the radial side of the forearm between the brachialis and the triceps muscle.
Size  5 × 22 cm.
Origin  Lateral supracondylar ridge of the humerus and lateral intermuscular septum.
Insertion  Styloid process of the radius.
Function  Arm flexion.
Composition  Muscle.
Flap Type  Type II.
Dominant Pedicle  Radial recurrent artery.
Minor Pedicle  Muscular branches of radial artery.
Nerve Supply  Motor: Lateral muscular branches of radial nerve.
Section 8B

UPPER EXTREMITY

Brachioradialis Flap

CLINICAL APPLICATIONS

Regional Use
  Upper extremity

Distant Use
  Head and neck
  Upper extremity

Specialized Use
  Tendon transfer
ANATOMY OF THE BRACHIORADIALIS FLAP

**Fig. 8B-1**

**Dominant pedicle:** Radial recurrent artery
ANATOMY

**Landmarks**
Lies on the radial side of the forearm between the brachialis and the triceps muscle.

**Composition**
Muscle.

**Size**
5 × 22 cm.

**Origin**
Lateral supracondylar ridge of the humerus and lateral intermuscular septum.

**Insertion**
Styloid process of the radius.

**Function**
Arm flexion.

Arterial Anatomy (Type II)

**Dominant Pedicle**  
*Radial recurrent artery*

**Regional Source**  
Radial artery.

**Length**  
3 cm.

**Diameter**  
1 mm.

**Location**  
Radial recurrent artery is in close proximity to the radial nerve and provides two terminal branches to the proximal deep surface to the muscle.

**Minor Pedicle**  
*Muscular branches of radial artery*

**Regional Source**  
Radial artery.

**Length**  
1 cm.

**Diameter**  
0.6 mm.

**Location**  
Segmental branches of the radial artery enter the muscle belly on its deep surface.

Venous Anatomy

Venae comitantes of the radial recurrent artery.

Nerve Supply

**Motor**  
Lateral muscular branches of the radial nerve.
VASCULAR ANATOMY OF THE BRACHIORADIALIS FLAP

Deep surface of flap

Radiographic view

Fig. 8B-2

Dominant pedicle: Radial recurrent artery (D)

FLAP HARVEST

Design and Markings
A dorsal radial incision is made overlying the muscle.

Radial incision over muscle

Fig. 8B-3
**Patient Positioning**
The patient is placed in the supine position. The arm is placed on a hand surgery table, abducted 90 degrees at the shoulder. A tourniquet is used.

**GUIDE TO FLAP DISSECTION**
A dorsal radial incision is made from the level of the lateral epicondyle to the distal third of the forearm. The posterior antebrachial cutaneous nerve and the lateral antebrachial lateral cutaneous nerve are identified and preserved. The tendon of insertion is identified in the distal forearm. The superficial branch of the radial nerve, which crosses dorsally, is preserved. The distal tendon is divided and the muscle is elevated proximally. The superficial branch of radial nerve and radial artery are located beneath the brachioradialis muscle and are retracted medially. The dominant vascular pedicle of the radial recurrent artery can be seen entering the deep surface of the muscle. This marks the rotation point for muscle transposition, and no further dissection is required.

![Flap after release of insertion](image1)
![Closeup view](image2)

![Flap elevated to show deep surface](image3)
![Closeup view](image4)

**Fig. 8B-4**

**Dominant pedicle:** Radial recurrent artery *(D)*
FLAP VARIANT

Free Flap
Dissection proceeds similar to that of the standard flap. The pedicle in this case is dissected proximally to its junction of the radial artery and venae comitantes. The radial artery and venae comitantes are divided distal to the radial recurrent artery, and the proximal radial artery and venae comitantes are dissected proximally until adequate pedicle length has been obtained. The muscle is then released from its origin in the posterior humerus.

If the motor nerve is required for functional transfer, the radial nerve is dissected proximally superior to the level of the radial condyle where the motor branch is identified entering its deep surface.

The distal section of the brachioradialis muscle can be carried with the radial forearm free flap (see Section 8D) based on its minor pedicle. As the radial forearm flap is dissected, in this case muscular branches from the radial artery are preserved, providing vascularization to the muscle.

ARC OF ROTATION
Based on its proximal vascular pedicle, the muscle will reach the antecubital fossa, upper elbow, and distal upper arm.

![Arc of rotation to elbow and antecubital fossa](Fig. 8B-5)

FLAP TRANSFER

Standard Flap
The flap is transferred by transposition to the recipient site.

Free Flap
Transfer of the brachioradialis as a free flap is performed using microsurgical principles.

FLAP INSET
The tendinous portion of the brachioradialis is used to secure the flap in place. Care is taken to ensure that there is no excessive tension on the pedicle or kinking of the blood supply.

DONOR SITE CLOSURE
Primary closure of the donor site is obtainable in all cases.
CLINICAL APPLICATIONS
This 47-year-old woman had a maxillary tumor excised, leaving a large skin defect, a small CSF leak, and open communication with the oropharynx. A radial forearm flap was chosen with multiple skin paddles for this complex reconstruction, as well as some brachioradialis muscle for repair of the CSF leak and soft tissue fill.

Fig. 8B-6  A, The defect after resection. The area of CSF leak was in the posterior orbit after exenteration. The facial vessels were exposed in the neck as the recipient site. B, The flap has been elevated. The larger skin paddle is for external skin coverage, the smaller for palatal repair. The long vascular pedicle will reach the neck without vein grafts or an A-V loop. The cephalic vein has been taken with the flap as well. C, The undersurface of the flap is shown, with the brachioradialis muscle carried with the flap based on perforators from the radial artery. D, After flap inset. The muscle nicely covered the area of CSF leak, which healed uneventfully. E, Two months postoperatively, the flap has settled nicely, which is desirable if the patient will ultimately wear a prosthesis. F, Final result with external prosthesis in place. (Case supplied by MRZ.)
This 58-year-old truck driver sustained an open injury to the left elbow during a motorcycle accident. There was soft tissue loss over the lateral epicondyle with exposed bone, open radiocapitellar joint, and partial laceration of the triceps tendon.

Fig. 8B-7  A, Lateral soft tissue defect with exposed and ground-down lateral epicondyle. B, Dissection of the brachioradialis muscle. C, The muscle was elevated and D, rotated into the defect.
The donor site incision was closed for exposure and the muscle was transposed and sutured into the recipient bed. The muscle was covered with a split-thickness skin graft. The flap reconstruction is seen 1 month postoperatively. At 6-month follow up, the patient has good extension and flexion of the elbow. (Case courtesy Milan Stevanovic, MD.)
Pearls and Pitfalls

- Superficial and deep branches of the radial nerve are subject to injury during flap elevation.
- A tourniquet is recommended for flap dissection to maintain a bloodless field.
- Because of the size of the muscle and the paucity of perforator of the muscle to the skin, an overlying skin island is unreliable.
- Skin grafting of the muscle is recommended when skin coverage is necessary.

EXPERT COMMENTARY

Milan Stevanovic

Anatomic Considerations

The brachioradialis is a useful flap for local coverage of small to moderate soft tissue defects on the posterior and lateral sides of the elbow. There is little functional deficit to the donor site. Both the dominant arterial pedicle and the innervation to the muscle are proximal. Preservation of the innervation to the muscle reduces the atrophy and fibrosis seen in de-nervated muscle transfers.

The dominant arterial pedicle can arise from the brachial artery, recurrent radial artery, or radial artery. All of the dominant pedicles enter the muscle in its proximal third, leaving the distal two thirds of the muscle to be rotated. In addition, the muscle origin from the lateral humerus can be released, increasing the ability to mobilize and rotate the flap.

![Image of brachioradialis anatomy](image)

**Fig. 8B-8** The brachioradialis is shown disinserted distally. The muscle origin from the distal lateral humerus is seen on the left side of the photo. Vascular pedicles from the radial recurrent artery are shown entering the muscle belly at the proximal third–middle third junction.

Unique to the brachioradialis anatomy is the wide distal tendon that can be used as a vascularized graft for reconstruction of the lateral ulnar collateral ligaments of the elbow. It can also be used for reconstruction or augmentation of the distal triceps tendon.
Recommendations

Technique

The muscle should be dissected through a long incision over the middle of the muscle. The distal insertion is divided from the distal radius. If tendon length is not needed, the muscle is divided proximal to where the first extensor compartment muscles cross over the brachioradialis tendon. The dissection can be performed with loupe magnification, from distal to proximal. More proximally, the muscle is mobilized from lateral to medial. The pedicles in the proximal third are all left intact until the muscle has been completely dissected. Proximally, the radial nerve lies on the medial side of the brachioradialis muscle between brachioradialis and brachialis.

The fascia should be completely released to allow more mobility to the muscle. After determining the dominant pedicle, several distal branches can be ligated to allow a greater arc of muscle rotation. If the tendon is needed for lateral ulnar collateral ligament or triceps tendon reconstruction, the reconstruction is completed first, and the muscle belly is subsequently positioned to cover the soft tissue defect.

Take-Away Messages

The brachioradialis flap is ideal for small to moderate defects of the lateral, posterolateral, and posterior elbow and can be used for lateral ulnar collateral ligament or triceps tendon reconstruction. A greater arc of rotation can be achieved by releasing the fascia and the proximal origin and leaving only the proximal dominant pedicles. The surgeon must take care to protect the radial nerve during proximal medial dissection. After the muscle is rotated, the pedicles should be inspected to confirm that there is no tension or kinking of the pedicles.

Bibliography With Key Annotations


The authors treated a patient with traumatic skin and bone loss at the elbow using a long brachioradialis flap, which provided a thick, sensate cover and allowed early movements. Anatomic studies helped describe the extent of this flap.


The authors explored the blood supply of the forearm, an area whose angiosome was not previously described in the classic work by Drs. Taylor and Palmer in 1987. Ten upper limbs from fresh cadavers were perfused with a radiopaque lead oxide solution. The arteries to the skin and the bones of the forearm and a total of 200 muscles were examined. The angiosomes in the forearm supplied by the brachial, radial, ulnar, and interosseous arteries were defined. The contribution from each angiosome to the skin, muscles, radius, and ulna was identified. Territories were color coded to correspond with source arteries. The authors reported that the connections between adjacent angiosomes occurred predominantly within tissues, not between them. The skin, bones, and most muscles received branches from the source arteries of at least two angiosomes, explaining how circulation is maintained if a source artery is interrupted by disease or trauma. Alternatively, several muscles were supplied within one angiosome, explaining the variable clinical responses to interrupted circulation (for example, Volkmann’s ischemic contracture). Results of this study are useful for designing flaps from the forearm for local or free transfer. Because most muscles are nourished from multiple angiosomes, techniques can be refined to include only a part of a muscle. This anatomic information also explains how the supply to remaining muscle groups is reconstituted when one of the source arteries is harvested with a skin flap, a muscle, or part thereof.


The authors studied the vascular anatomy and defined cutaneous territories of the brachioradialis myocutaneous flap in cadavers using intraarterial injection of methylene blue dye. They discuss treatment of an exposed, open elbow joint with a proximal brachioradialis myocutaneous flap, based on the vascular pedicle arising from the radial recurrent artery just distal to the elbow level. Advantages and disadvantages of this flap are presented.


The authors performed a two-part vascular injection study to determine (1) the sources of blood to the brachioradialis muscle and the distance the brachioradialis muscle flap may be rotated for local soft tissue reconstruction and (2) the fasciocutaneous vascular perfusion territory associated with the vascular pedicle of the brachioradialis muscle flap. To reveal the contribution of the isolated radial recurrent artery (RRA) and 3 cm and 6 cm segments of radial artery (RA) to a rotation brachioradialis muscle flap, they injected lead oxide into 16 fresh frozen human upper extremity amputation specimens. The RRA perfused an average of 41% of the brachioradialis muscle. Selective injection of the RRA and the proximal 3 cm segment of the RA perfused 80% of the muscle length, or at least 90% of muscle volume. Flap rotation consistently provided adequate coverage of the antebrachial fossa, lateral elbow, and proximal third of the volar forearm. To quantify the fasciocutaneous perfusion territory of the isolated vascular pedicle, India ink injection studies were performed in 10 fresh frozen cadaveric specimens. Fasciocutaneous perfusion was consistent directly over the muscle belly, but no specimen was perfused more than about 1 cm distal to the myocutaneous junction.


The authors describe their experience with the brachioradialis muscle flap based distally on the radial artery. They conclude that it can be raised quickly and provides excellent coverage for soft tissue defects of the hand. The use of the brachioradialis tendon for extensor tendon reconstruction is also discussed.


With careful preoperative planning, the brachioradialis muscle can provide adequate surface area for covering the deep antebrachial neurovascular structures, often required after a chronic elbow flexion contracture is released. Local rotation or transposition flaps can cover skin defects, but not deeper structures.
The brachioradialis muscle is a secondary flexor of the elbow and has a robust vascular anatomy that can support a skin paddle. Its removal causes minimal functional morbidity.


To determine the blood supply to the brachioradialis muscle and skin of the forearm, the authors performed late-injection studies. The dominant perforator to the muscle was from the brachial artery (27.3%), radial recurrent artery (33.3%), or radial artery (39.4%). Perforators from the radial artery were consistently present, confirming that transfer as either a muscle or myocutaneous free flap based on this vessel is possible. The authors dissected the septocutaneous perforators from the radial artery in 10 arms to examine the relationship between the forearm and brachioradialis flaps. It is possible to transfer the brachioradialis muscle as a free flap or combined with the radial artery forearm flap based on the radial artery and either the venae comitantes and/or the cutaneous veins. Four clinical cases were presented.


The authors retrospectively reviewed all vascular thromboses and intraoperative technical difficulties with free flaps performed in a 5-year period in one institution to determine whether intraoperative vascular complications predict postoperative vascular thrombosis and flap loss. All flaps were performed for breast reconstruction. They compared flaps with a routine intraoperative course with those that had an intraoperative complication. They reviewed data from 173 free flaps in 804 patients and conclude that intraoperative vascular problems increase the risk of a postoperative vascular complication and flap loss. Postoperative vascular complications are apparently not overtly affected by specific surgical intervention or choice of anticoagulation during an intraoperative problem.


The authors compared the neurovascular anatomy of the brachioradialis and flexor carpi ulnaris muscles to evaluate their possible use as donor muscles, together with overlying skin, for functional total or subtotal tongue reconstruction. They examined 88 brachioradialis and 80 flexor carpi ulnaris muscles from a total of 120 dissected specimens. They also performed 18 arterial studies, two venous studies, 20 histologic studies, and eight neurovascular studies. In the brachioradialis muscle, the major pedicle arose from the radial (38%), radial recurrent (42%), and brachial arteries (20%). The muscle had no single neurovascular pedicle. With the flexor carpi ulnaris muscle, the ulnar artery consistently supplied the dominant pedicle in 86% of cases. The entry point of motor innervation is near that of the vascular pedicles. The main vascular pedicle was accompanied by a minor distal nerve in 65% of cases. The overlying skin was supplied by myocutaneous perforators. The skin over the brachioradialis was innervated by the lower lateral cutaneous nerve of the arm. Sensation over the flexor carpi ulnaris was from the medial cutaneous nerves of the arm and forearm. In conclusion, the flexor carpi ulnaris has anatomic advantages over the brachioradialis for total or subtotal tongue reconstruction.


The authors presented a case of upper lip reconstruction with a free radial forearm flap. The procedure was performed in one stage, with excellent aesthetic and functional results. In conclusion, the free radial forearm flap, including the vascularized and innervated brachioradialis muscle, is useful for a variety of lip defects.
ANATOMIC LANDMARKS

**Landmarks**
Flap is centered on a line between the lateral humeral epicondyle and distal radial joint in the midforearm, between the radial and ulnar bones.

**Size**
15 × 7 cm.

**Composition**
Fasciocutaneous.

**Dominant Pedicle**
Posterior interosseous artery (PIA).

**Minor Pedicle**
Anterior interosseous artery (AIA).

**Nerve Supply**
*Sensory:* Lower branch of the dorsal antebrachial nerve (C5 to C8). Medial antebrachial cutaneous nerve (C8 to T1).
Section 8C

UPPER EXTREMEITY

Posterior Interosseous Flap

CLINICAL APPLICATIONS

Regional Use
  Elbow
  Forearm
  Wrist
  Hand
Fig. 8C-1

**Dominant pedicle:** Posterior interosseous artery

**Minor pedicle:** Anterior interosseous artery
ANATOMY

Landmarks  Flap is centered on a line between the lateral humeral epicondyle and distal radial joint in the midforearm, between the radial and ulnar bones.
Composition  Fasciocutaneous.
Size  $15 \times 7 \text{ cm}.$

Arterial Anatomy

Dominant Pedicle  *Posterior interosseous artery*
Regional Source  Common interosseous artery or ulnar artery.
Length  5 cm.
Diameter  1.5 mm.
Location  Posterior interosseous artery: 1 cm after origin from the ulnar artery, the common interosseous artery divides into the anterior and posterior interosseous arteries. The PIA, which is smaller than the AIA, passes between the oblique cord in the upper border of the interosseous membrane. It emerges at the lower border of the supinator in the lower forearm. It descends in the intermuscular septum between the extensor carpi ulnaris and extensor digiti minimi. In the proximal third of the forearm, the PIA lies deep with the posterior interosseous nerve. More distally, it becomes superficial on the extensor pollicis longus and the extensor indicis muscles. The PIA receives an anastomotic branch from the AIA 3 cm proximal to the distal radial ulnar joint and then extends to join a dorsal carpal arch. In the intermuscular septum between the extensor carpi ulnaris and extensors digiti minimi, the PIA gives off four to seven septocutaneous perforators as well as muscular branches. In its middle third, the PIA consistently gives off a middle cutaneous perforator, the vena comitans of which is a communicating vein between the superficial and deep veins of the flap. Because of this, this perforator should be included in the flap to improve drainage.

Minor Pedicle  *Anterior interosseous artery*
Regional Source  Common interosseous artery or ulnar artery.
Length  4 to 5 cm.
Diameter  1.5 to 1.7 mm.
Location  Pedicle courses on the palmar surface of the interosseous membrane deep to the flexor digitorum profundus and flexor pollicis longus muscles. At the superior border of the pronator quadratus the pedicle pierces the interosseous membrane to anastomose with the PIA.

Venous Anatomy

There are one or two venae comitantes that accompany the PIA, with diameters of 2 to 3 mm.

Nerve Supply

Sensory  Lower branch of the dorsal antebrachial nerve (C5 to C8), pierces the deep fascia beneath the level of the deep deltoid. The nerves course along the lateral side of the upper arm and elbow and enter the flaps on the dorsal forearm. The medial antebrachial cutaneous nerve (C8 to T1) courses medially to the basilic vein and anterior to the medial epicondyle.
VASCULAR ANATOMY OF THE POSTERIOR INTEROSSEOUS FLAP

Fig. 8C-2  The distally based posterior interosseous flap can be designed based on the anterior interosseous artery perforator and is dependent on the arcade of vessels running between the anterior interosseous artery and the posterior interosseous artery, between the extensor digiti minimi and extensor carpi ulnaris. Flaps can also be based on individual perforators of the posterior interosseous artery. (Dissection courtesy Steven F. Morris, MD.)

FLAP HARVEST

Design and Markings
The PIA flap is drawn centered on a line from the lateral epicondyle of the humerus to the distal radial ulnar joint. The flap is centered at the middle and distal thirds of the line with a width of 5 to 7 cm. Distally, the flap ends 4 cm above the wrist joint to avoid damaging the dorsal branch of the ulnar nerve. The flap may extend superficially 2 to 3 cm above the emergence of the PIA.

Patient Positioning
The patient is placed in a supine position with the arm on a hand table.
GUIDE TO FLAP DISSECTION
The radial border of the flap is incised through the deep fascia and is then elevated toward the intermuscular septum. Once the extensor digiti minimi is reached, the septocutaneous perforator of the PIA can be visualized.

These perforators are traced to the intermuscular septum between the extensor carpi ulnaris and the extensor digiti minimi. After the muscular branches are ligated, retraction of the extensor digiti minimi radially exposes the PIA. With further dissection, the communicating branch with the AIA can also be identified.
The ulnar border of the flap is incised, carefully preserving the dorsal branch of the ulnar nerve after the PIA and its perforating branches are visualized. The anastomotic branch of the AIA is ligated, and the flap is elevated from distal to proximal.

Pedicle dissection occurs between the extensor carpus ulnaris and the extensor digiti minimi. The posterior interosseous nerve lies radial to the artery and the nerve should be protected. After ligation of the interosseous recurrent artery the posterior interosseous vascular pedicle is dissected proximally beneath the supinator muscle.
**FLAP VARIANT**

**Reverse Flap**

The flap design is positioned more proximally compared with that of the standard flap. The design is mainly in the middle third of the forearm, again on a line from the lateral epicondyle of the humerus to the distal radial ulnar joint.

The rotation point for the flap is 3 cm proximal to the distal radial ulnar joint. The radial border of the flap is incised and raised with the deep fascia toward the intermuscular septum. Dissection proceeds in the septum to expose the PIA and nerve in the midpoint of the PIA. The surgeon carefully identifies the middle septocutaneous perforator, which contains the communicating vein between the superficial and deep system in the forearm. This perforator should be included in the flap to improve venous drainage.
The skin incision is then extended distally along the line of the intermuscular septum. The cutaneous perforator is identified and preserved. Retraction of the forearm muscles exposes the posterior interosseous vessels. Dissection proceeds distally to identify the anastomotic branch with the AIA, which comes from beneath the extensor indicis proprius. All branches that join the dorsal carpal arch distally must be preserved.

After flap elevation, the surgeon may clamp the proximal vessels and release the tourniquet to assess perfusion of the flap through this retrograde supply. After this is confirmed, the proximal end of the vascular pedicle is ligated.
ARC OF ROTATION

Standard Flap
The standard flap covers defects on the antecubital fossa and proximal volar forearm.

Arc to antecubital fossa and proximal forearm

Fig. 8C-6

Reverse Flap
A reverse flap will cover defects of the distal wrist, hand, first web space, and proximal thumb.

Point of rotation

Arc to hand

Fig. 8C-7
FLAP TRANSFER

Standard and Reverse Flaps
Flaps are transferred by transposition to the recipient site with direct incision or through a subcutaneous tunnel.

FLAP INSET

All Types
The flap is inset without tension; the vascular pedicle must not be compressed.

DONOR SITE CLOSURE
With a skin island of less than 6 cm, primary closure is possible. A larger skin island requires skin grafting.
CLINICAL APPLICATIONS

This 51-year-old man developed a malignant fibrous histiocytoma in the distal forearm and wrist area. A reverse PIA flap was chosen for reconstruction. This flap is available locally, with good color and texture match.

Fig. 8C-8  A and B, The tumor was resected widely to include the radial artery and radial sensory nerve and the tendons of the abductor pollicis longus, flexor carpi radialis, and extensor pollicis brevis muscles.  C and D, A reverse pedicled PIA perforator flap was designed to cover the soft tissue defect.  E, The radial artery was reconstructed with a vein graft. The tendon defects of the abductor pollicis longus, flexor carpi radialis, and extensor pollicis brevis muscles were reconstructed using a palmaris longus graft. A reversed posterior interosseous pedicled flap was raised.  F, The PIA perforator flap was inset in the defect.  G and H, The result is seen 2 years and 10 months after surgery. There is no radial sensory nerve irritation, the vein graft to the radial artery is patent, and the skin color and contour match are excellent. (Case courtesy Minoru Shibata, MD.)
This boy, 3 years and 4 months old, presented with brachysyndactyly of the left thumb. A reverse PIA flap is an excellent choice for reconstruction of first web defects, such as the one created by this secondary reconstruction.

Fig. 8C-9  A and B, The patient had undergone previous surgery for closure of the left interdigital space and separation of the syndactyly of the two radial digits. C, The surgical plan was to widen the first interdigital space and remove the second metacarpal bone. A PIA flap was planned for coverage of the soft tissue defect created by the widened first web space. D and E, The PIA perforator flap was elevated and transposed into the first web space soft tissue defect. F-I, The flap healed well, with primary closure of the donor site. The results are shown 5 months postoperatively, with improved function, good color match, and an acceptable donor site scar. (Case courtesy Minoru Shibata, MD.)
This 32-year-old man had injured the first web space of his right hand. He developed a contracture of the first web space that required release of soft tissue, fascia, and joint capsule to restore function. A distally based PIA flap was used to close the defect.

**Fig. 8C-10**  
A, The first web space defect is shown.  
B, A distally based PIA flap was designed at the junction of the proximal and middle thirds of the extensor forearm.  
C, The flap was incised on the radial and ulnar sides down through the antebrachial fascia and dissected to the pivot point approximately 5 to 6 cm proximal to the distal radioulnar joint. It was elevated in a proximal to distal fashion, while carefully noting the cutaneous perforators within the septocutaneous fascia between the extensor digiti minimi and the extensor carpi ulnaris muscles. The posterior interosseous artery was elevated at the base between these muscles. The proximal end of the feeding vessel to the flap was ligated as it exited distal to the supinator muscle. The flap was tunneled into position.  
D and E, The flap and donor site are shown after inset. The donor site was closed primarily.  
F and G, Early postoperative results show good range of motion with adequate preservation of the first web space. (Case courtesy Guenter Germann, MD.)
This 25-year-old farmer caught his right hand in the power take-off on a farm tractor, resulting in amputation of four fingers of his right (dominant) hand. They were nonreplantable. The wound was reconstructed with a distally based PIA flap.

Fig. 8C-11  
A, The appearance of the wound after debridement.  
B, Radiograph of the amputation through the midmetacarpal level.  
C, The PIA flap was designed between the distal radioulnar joint and the lateral epicondyle. Flap dimensions were 15 by 10 cm.  
D and E, The flap was elevated on the posterior forearm and transposed into position.  
F and G, The healed flap provides complete wound closure. There were no complications. (Case courtesy Steven F. Morris, MD.)
Pearls and Pitfalls

- The flap is most commonly used as a reverse flap to cover defects of the hand or wrist.
- Use of a tourniquet is recommended for flap elevation and identification of the posterior interosseous pedicle and motor nerve branches in the vicinity.
- For the reverse flap, a wide tunnel is required to avoid compression of the minor pedicle beneath the skin bridge.
- If there is inadequate venous drainage of the flap, anastomosis may be performed between the superficial vein at the distal flap edge and the hand.
- Whether reverse or free, the posterior interosseous flap is advantageous in that it does not require division or sacrifice of a major artery of the hand.
- This donor site provides a skin flap with good texture, thinness, and color match for hand reconstruction.

EXPERT COMMENTARY

Michael W. Neumeister

The PIA flap was first described by Angrigiani and Zancolli in 1986, and by Penteado and Masquelet in the same year. The flap is versatile because of its long pedicle, location, and ability to cover the dorsal or volar aspect of the hand, forearm, and elbow. It can also be harvested as a free flap and used for recipient sites throughout the body.

Indications

The main indication for the PIA flap is coverage of dorsal hand and first web space defects. The flap is typically harvested as a reverse-flow pedicled flap based at the wrist, with direct communications with the anterior interosseous artery on the volar aspect of the forearm. The reverse-flow PIA flap is also indicated for volar forearm and hand defects. As an antegrade flap, it be used to cover more proximal forearm defects, including those on the anterior and posterior aspects of the elbow.

Advantages and Limitations

The main advantage of the PIA flap is that it can be used as a regional pedicled flap for coverage of elbow, forearm, wrist, and hand defects. It can be harvested as a fascial flap, fasciocutaneous flap, or osteocutaneous flap. As noted previously, it can be harvested as an antegrade or retrograde flap, allowing versatility in its design and application. Microsurgery is not required, although occasionally venous outflow can be augmented through an anastomosis with superficial veins within the skin paddle.
The flap has numerous limitations. The artery itself can be extremely small, particularly at its most distal aspect. The main perforator into the skin paddle can also be too distal to provide optimal pedicle length for skin coverage in the hand. The dissection can be rather tedious where the vessel courses between the extensor carpi ulnaris and the extensor digiti quinti muscles. The pedicle can be somewhat more superficial toward the distal forearm and wrist, so caution is warranted as the dissection proceeds distally. The blood supply to the skin paddle can be somewhat precarious, especially if larger amounts of tissue are required for a given defect. Flap necrosis and partial necrosis can occur. If the donor site is wider than 6 to 7 cm, it cannot be closed primarily. Flaps designed with a smaller width can be closed primarily; otherwise, a split-thickness skin graft is required for closure.

**Anatomic Considerations**

The main perforator for the PIA flap arises just distal to the supinator muscle in the junction between the proximal third and distal two thirds of the extensor forearm. The flap can be designed distally or proximally around this middle third. The posterior interosseous artery communicates with the anterior interosseous artery at a level approximately 5 cm proximal to the ulnar styloid. This is the pivot point for the flap if it is distally based. A Doppler study should be performed preoperatively to help locate the perforators within the skin paddle.

**Personal Experience and Insights**

For dorsal hand or first web space defects, the flap is islandized on its pedicle and can be tunneled into the first web space quite easily. Taking an extended skin paddle distally in the shape of an ice cream cone can also aid in the flap inset if tunneling seems too constractive. The flap is usually quite narrow; therefore the posterior interosseous artery flap should be used for smaller defects only. The skin paddle is usually not very bulky, but the donor site can often leave significant scars, which limits the use of this flap, in my experience. I find this flap to be rather tedious in its dissection, limiting its use. The major benefit of this flap is that it is a regional flap located close to the zone of injury, and it does not utilize one of the major arteries to the hand. The pedicle can be rather small near the pivot point at the wrist; therefore, care must be taken not to avulse or place tension on the pedicle, which would compromise the skin paddle.

If the flap is tunneled, the surgeon must not place undue pressure on the pedicle, because this will result in vascular compromise and flap necrosis. Many surgeons opt not to tunnel the flap but instead divide the bridge from the pivot point of the flap to the defect on the hand. Flap congestion can occur; therefore the superficial vein should be preserved within the flap so that venous outflow can be reestablished through a microsurgical anastomosis.

Better donor flaps are available for larger defects on the hand or first web space. The skin paddle can be as wide as 10 cm based on the posterior interosseous artery, but the donor site would require skin grafting, and in my opinion, that creates too much scar tissue and is extremely unsightly. This flap should not be used if the defect is large.

**Recommendations**

**Planning**

To design the flap, the pedicle is identified first. The arm is positioned in pronation and a line drawn from the lateral epicondyle to the distal radioulnar joint. This line is divided into thirds, and Doppler ultrasonography is used to identify the perforator, which should emerge around the level of the junction of the proximal third and distal two thirds of that line.
This is located approximately 7 to 10 cm distal to the lateral epicondyle. Fig. 8C-12 illustrates the design of the skin paddle and a reverse posterior interosseous artery flap.

**Technique**

The radial incision is made and the dissection carried down through the antebrachial fascia toward the intermuscular septum between the extensor carpi ulnaris and the extensor digiti quinti. The posterior interosseous artery should be identified between these muscle bellies at the level of the interosseous membrane. The posterior interosseous nerve should be preserved at this level. As this nerve enters the dorsal compartment of the forearm, it supplies the extensor carpi ulnaris, extensor digiti quinti, and extensor digitorum communis. The nerve and artery may crisscross in the more proximal aspect of the forearm. The nerve is usually more radial and deeper than the artery. Before becoming a sensory nerve, the posterior interosseous nerve innervates the abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, and extensor indicis proprius, which is the last muscle belly innervated by the nerve. Care must be taken not to denervate the extensor muscles while dissecting the pedicle of the posterior interosseous artery flap. The dorsal cutaneous branch of the ulnar nerve should also be preserved as the dissection is carried from proximal to distal. The dorsal cutaneous branch of the ulnar nerve is often found 6 cm proximal to the ulnar carpal joint.

It is often easier to raise the flap from radial to ulnar until the septum is identified between the extensor carpi ulnaris and the extensor digiti quinti muscles. The muscles are then retracted as the flap is elevated from proximal to distal. The posterior interosseous artery is ligated as it emerges from the distal aspect of the supinator. The posterior interosseous nerve is dissected to free up the pedicle, at least until the final branches to the extensor indicis proprius have been located. The flap is then transferred into the defect on the dorsum of the hand or first web space. A Penrose drain is placed for drainage from below the flap, and the donor site is closed primarily. A volar wrist splint is applied for approximately 2 weeks after the surgery, and subsequently, range of motion exercises are initiated.

The PIA flap can also be harvested as a sensate flap, preserving branches of the posterior cutaneous nerve of the forearm. Other variations of the flap elevation include harvesting the flap as a fascial flap or osteocutaneous flap. The small portion of the extensor pollicis longus muscle belly must be harvested with the ulna to preserve the vascularity, because a small segment of bone is required with the flap.
Bibliography With Key Annotations


The authors reviewed a series of 15 consecutive patients with various hand defects covered with a distally based posterior interosseous flap. Twelve flaps survived completely. Partial distal necrosis occurred in three flaps; no surgery was required. One patient developed radial nerve palsy that resolved after 3 months. In flaps 4 cm wide or less, the donor site was closed directly, and larger flaps were skin grafted. Main indications were presented.


The goal of this report was to better understand the relationship between flap necrosis and the placement of the flaps on the forearm. The authors reviewed 87 consecutive posterior interosseous island flaps used for hand and wrist reconstruction. Fifty-eight flaps were from the middle and proximal thirds of the forearm. In 24 of these, the distal edges were within the middle third of the forearm, and, in 34 the distal edges were within the distal third of the forearm. Twenty-nine flaps were harvested within the boundaries of the distal two thirds of the forearm. Seventy-eight flaps completely survived. Superficial necrosis occurred in the distal part of three flaps. Three flaps failed. Partial necrosis appeared to be related to the donor site. The authors concluded that the reverse posterior interosseous flap should include the septocutaneous perforators in the distal third of the forearm. To cover distant defects by a flap with a long pedicle, the flap should extend up to the distal third of the forearm to include a piece of skin with numerous perforators.


The authors shared their experience using the reverse-flow posterior interosseous artery flap in 53 patients. Defects included small defects on the dorsum of the hand, first web, and volar aspect of the wrist, as well as combined defects on the dorsum of the hand and forearm, palm, and first web, extending onto the dorsum of the hand. They discussed modifications in how they raised the flap and in the shape and route of transposition to avoid pedicle compressions. Tip necrosis occurred in four flaps, and the pincushion effect occurred in 10 flaps. One patient developed a hypertrophic scar. Advantages and disadvantages were described.


The authors shared their results using the posterior interosseous free flap with an extended pedicle in nine patients with hand defects. All flaps were designed over the dorsal distal forearm, and donor sites were closed directly. All transfers were successful, and donor site morbidity was minimal. The authors concluded that, despite the tedious dissection required, the vascular pedicle was suitable for microanastomosis. The skin island was thin, though hairy. The posterior interosseous free flap with an extended pedicle may be a good choice when thin skin is limited and a long vascular pedicle is needed.


The authors presented results from nine patients who underwent reconstruction following metacarpal hand amputations. In the primary reconstructions (six), the posterior interosseous pedicled flap provided skin coverage to the metacarpal stumps. In the three delayed cases, the flap provided extra skin for operations performed at a later date. All flaps survived. One required venous supercharging because of venous supercharging. Advantages and disadvantages of this flap were discussed.

Over the course of 10 years, the authors performed a reverse-flow posterior interosseous flap in 68 patients. Sixty-six flaps were fasciocutaneous, and two were osteofasciocutaneous. These flaps were used for volar and dorsal traumatic hand defects, first web space defects, thumb reconstruction, and repair of congenital anomalies. Sixty flaps survived uneventfully. Four flaps developed partial necrosis, and four flaps completely necrosed. The authors concluded that the most important factor for flap survival was the inclusion of at least two perforators to supply the skin paddle.


Based on their results of 102 clinical cases and 100 anatomic dissections, the authors reported the indications for the posterior interosseous flap for reconstructing hand defects. Even when the radial or ulnar pedicles were damaged, large fasciocutaneous island flaps could be harvested. One advantage is that the posterior interosseous artery is a vessel of secondary importance for hand vascularization. Fasciocutaneous and osteofasciocutaneous island distally based flaps could be tailored. The major indications for this flap are reconstruction of the first web space up to the interphalangeal joint of the thumb, dorsal hand defects up to the metacarpal joints, and large defects on the palm-ulnar border of the hand.


The authors presented their experience of successfully transplanting two free posterior interosseous artery perforator flaps that had been harvested simultaneously from a single posterior interosseous artery system to the index and middle fingers of a 19-year-old man.


The authors performed the posterior interosseous flap in 30 patients to close defects on the dorsum of the hand. In four other patients, free lateral arm and temporoparietal fascial flaps were used because of severe trauma to the wrist and distal forearm with potential impairment of the pedicle, a complex defect requiring a composite flap, or an anatomic variation. All flaps survived. Marginal flap necrosis developed in two posterior interosseous flaps. Flaps based on the main vessels of the forearm were not used because of their significant donor site morbidity.


The authors reported their experience using the reverse posterior interosseous flap and its composite flap in 201 cases. The fasciocutaneous flap was used to cover skin defects over the distal third of the forearm, wrist, and hand. The composite flap with the vascularized ulna bone graft was used to reconstruct thumbs in 11 cases, and the composite flap with vascularized tendon graft was used to repair tendon defects with skin defects in 16 cases. One flap failed completely. Of the 200 flaps that survived, 16 had venous congestion and partial necrosis at the distal end. Six months postoperatively, in all patients who were followed, the flap generally matched surrounding skin. However, 10 cases had a lipoctomy. The sensibility did not recover or achieved S1 within 6 months. For the extensor tendon defect, the function of finger extension was nearly normal, and tenolysis was not required. In contrast, tenolysis was required after the flexor tendon reconstruction, but these patients refused surgery. Bone
grafts healed within 3 months. The reconstructed thumb looked abnormal, but lacked normal sensibility, although the patients used them. The authors concluded that the reverse posterior interosseous flap was a reliable method to cover skin defects over the distal third of the forearm, wrist, and hand.


In this article, the authors focused on the surgical technique, specific limitations, and indications for the radial forearm fascial flap, the posterior interosseous artery flap, the retrograde radial artery perforator flap, and the dorsal ulnar artery flap. They proposed a reconstructive algorithm for flap selection.


The authors performed 12 posterior interosseous free flaps, including two dual-paddle flaps, and reported their clinical experience and surgical methods. The posterior interosseous vessels were ligated below the level where the motor branch to the extensor carpi ulnaris crossed the vessel superficially. All donor sites were closed directly. All flaps survived completely. Results were cosmetically acceptable in all but one patient in whom defatting of the flap was performed in the late postoperative period. Static two-point discrimination scores averaged 11 mm. Seven patients had normal joint flexion and extension. Two patients with fracture and flexor injuries recovered near-normal flexion and extension after flexor release. The other patients had partial preoperative joint stiffness and recovered partial flexion.


The authors attempted to improve the versatility of the posterior interosseous artery (PIA) flap to decrease flap complication rates. They used this flap to resurface 25 cases of distal forearm, hand, and finger defects. Flap types were: 23 adipofascial, 1 fascial, and 1 osteocutaneous. Doppler analysis was part of the preoperative planning. The anatomy and distal reach of the flap were noted. Flaps were raised from the zone of injury if Doppler confirmed the presence of good perforators. A large amount of fascia and subcutaneous tissue was included with the flap, which may have explained the survival of larger flaps, absence of venous congestion, and the low complication rate. To improve the distal reach of the flap to the distal interphalangeal joint, they exteriorized the pedicle, bowstringing it across the extended wrist. The pedicle was covered with a split-thickness skin graft and divided 3 weeks later under local anesthesia. Three minor complications occurred.


Anatomic variations in the posterior interosseous artery have been widely described and, in some cases, are the reasons cited for flap failures or conversion to alternative salvage procedures. The authors reported on a new technique, CTA, for imaging this artery preoperatively. This noninvasive method can be used to highlight anatomy to facilitate safe planning for alternative reconstructive options in complex cases. The authors described a unique case in which the posterior interosseous artery was completely absent throughout its course. With preoperative imaging, they were able to achieve a good outcome.


In this article, the authors reported on the possibilities for defect coverage with perforator flaps, and discussed anatomic and technical considerations. Lateral arm, posterior interosseous artery, ulnar artery, radial artery perforator flaps, and intrinsic hand flaps were described.

Treatment choices for restoring complex hand defects in children are limited. The reverse posterior interosseous flap is a versatile flap, with successful results shown in adults. The authors used this flap to repair complex hand defects in 10 children. Their average age was 9.1 years. Fasciocutaneous and osteofasciocutaneous flaps were used in 7 and 3 children, respectively. All flaps survived completely. The average time of bone union was 3 months. This flap was safe and versatile, with easy and rapid harvest. The diameter of the vessels was not a handicap in the flap dissection, and the operation time was short.


In this article, the authors introduced the reverse posterior interosseous flap for spaghetti wrist trauma. They performed the flap in 12 patients with skin defects over the volar wrist. The size of the skin defects ranged from 5 by 4 cm to approximately 10 by 6 cm. Donor sites were covered by a split-thickness skin graft. The follow-up period was at least 3 months. All flaps and skin grafts survived uneventfully. The texture, color, and thickness of the skin paddle matched the surrounding skin. The sensation of the flap recovered from S0 to S1 on a five-point scale. The functional recovery of the hand and fingers was dependent on the original injuries to the tendons and nerves. The authors concluded that the pedicle should include 2 cm of fascia and septum between the extensor carpi ulnaris and extensor digiti quinti proprius, and the subcutaneous tunnel should be wide enough to avoid venous congestion. They recommended temporarily blocking the proximal end of the posterior interosseous artery to observe the blood supply of the flap before completing the procedure.
### ANATOMIC LANDMARKS

| Landmarks | Large, well-vascularized fasciocutaneous flap primarily on the ventral aspect of the forearm that extends from the wrist crease to the antecubital fossa. |
| Size | 10 × 40 cm. |
| Composition | Fasciocutaneous; muscle and bone. |
| Flap Type | Fasciocutaneous, osteocutaneous, myocutaneous. |
| Dominant Pedicle | Radial artery. |
| Nerve Supply | Sensory: Lateral and medial antebrachial cutaneous nerves. |
Section 8D

CLINICAL APPLICATIONS

Regional Use
- Forearm
- Elbow
- Wrist
- Hand
- Thumb

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Esophageal reconstruction
- Penile reconstruction
ANATOMY OF THE RADIAL FOREARM FLAP

Arterial anatomy

Dominant pedicle: Radial artery

Venous anatomy

Nerve distribution

Fig. 8D-1
ANATOMY

Landmarks
This thin, well-vascularized fasciocutaneous flap can encompass nearly all tissues of the lower forearm; the size of the flap is limited only by morbidity at the donor site. Almost any part of the skin and fascia, from the wrist crease to the antecubital fossa, can be elevated based on the radial artery and its branches.

Composition
Fasciocutaneous. A segment of the radius can be elevated with the flap as an osteocutaneous flap, and the distal brachioradialis can be taken with the flap for additional muscle. A fascia-only flap can also be used.

Size
10 × 40 cm skin; bone 15 cm; muscle 6 cm.

Arterial Anatomy

Dominant Pedicle  
Radial artery

REGIONAL SOURCE  
Brachial artery.

LENGTH  
20 cm.

DIAMETER  
2.5 mm.

LOCATION  
Just below the elbow crease and distal to the bicipital aponeurosis, the brachial artery divides into the radial and ulnar arteries. The radial artery courses between the brachioradialis and the pronator teres muscles in the upper forearm, in between the brachioradialis and the flexor carpi radialis in the lower forearm. The artery originates deep to the brachioradialis and becomes more superficial distally in the arm. At the level of the wrist, the vessel passes deep to the tendons of the abductor pollicis longus and extensor pollicis brevis and continues into the anatomic snuffbox (the radial fossa), where it forms the deep palmar arch. The majority of the fasciocutaneous perforators from the radial artery are in the distal half of the forearm, where the vessel is more superficial. Although most perforators directly supply the overlying fascia and skin, there are some small perforators that are supplied through the brachioradialis, also based off of the radial vessel.

Venous Anatomy

There is both a deep and a superficial drainage system to the radial forearm flap. The superficial system is based off the cephalic vein, which is 20 cm long and 2.5 mm in diameter. The cephalic vein drains the radial portion of the dorsum of the hand. It courses around the radial border of the forearm, then runs on the ventral aspect of the forearm toward the antecubital fossa, where it joins the basilic vein. The deep system is based on paired venae comitantes that accompany the radial artery. The diameter of these comitantes is 1 to 1.5 mm. They run with the radial vessels and play an important role in drainage for any distally based flap. Depending on the location of the skin paddle, the venae comitantes may be the more dominant drainage system.

Nerve Supply

Sensory
The medial and lateral antebrachial cutaneous nerves of the forearm supply the skin territory of the radial forearm flap. The lateral antebrachial cutaneous nerve supplied by C5–C6 is the distal continuation of the myocutaneous nerve. This nerve arises from between the biceps brachii and the brachialis muscles. It pierces the fascia lateral to the biceps tendon in the cubital fossa, passes posterior to the cephalic vein, and divides into anterior and posterior branches. The larger anterior branch accompanies the cephalic vein into the forearm and supplies the skin of the radial half of the anterior surface as far as the thenar eminence. The smaller posterior branch supplies the skin of the radial border and posterior aspect of the forearm as far as the wrist.
The medial antebrachial cutaneous nerve (C8 to T1) arises from the medial cord of the brachial plexus and accompanies the brachial artery. At the junction of the middle and distal thirds of the arm, it passes with the basilic vein and divides into an anterior and ulnar branch. The anterior branch supplies the anterior medial surface of the forearm to the wrist; the ulnar branch passes anterior to the medial epicondyle and supplies the skin of the forearm on its posteromedial surface.

**Vascular Anatomy of the Radial Forearm Flap**

Fig. 8D-2

Dominant pedicle: Radial artery (D)

n, Lateral antebrachial cutaneous nerve; v, cephalic vein
**FLAP HARVEST**

**Design and Markings**

Positioning of the skin flap on the forearm depends on the nature of the defect to be reconstructed. For a pedicle flap to be used proximally on the arm, the skin paddle is positioned more distally to allow adequate arc of rotation to reach the reconstructive site. A Doppler probe is used to mark the location of the radial artery. A tourniquet can be placed on the arm preoperatively and the cephalic vein demarcated, because it is advantageous to include this in the design of the flap. For distally based reconstruction, the flap is designed more proximally in the forearm to allow adequate arc of rotation. Multiple skin islands can also be planned; these are centered along the axis of the radial artery.

![Diagram](image)

**Fig. 8D-3**  
A. The territory of this flap extends from below the antecubital crease proximally to the wrist flexion crease distally. The distal width is from the extensor hallucis longus tendon radially to the extensor carpi ulnaris tendon ulnarily. The proximal width is from the lateral to medial humeral epicondyles. B. A fasciocutaneous flap can be designed and placed proximally, centrally, or more distally on the forearm. Middle positioning is useful if the recipient pedicle is of suitable length and improves aesthetics by avoiding the wrist crease. Most perforators are in the distal half of the forearm. Proximal positioning is useful when designing a reverse-flow flap. C. An average flap measures 5 to 8 cm wide and 8 to 10 cm long. The flap is designed so that the lateral third of the flap is located lateral to the course of the radial artery.
Patient Positioning
The patient is placed in the supine position, with an armboard and a tourniquet around the upper arm.

GUIDE TO FLAP DISSECTION
When the surgeon is contemplating a radial forearm flap, it is important to test the vascularization of the hand based on the ulnar and radial vessels. A preoperative Allen's test should establish that the hand will be well vascularized on the ulnar artery alone. The flap is incised first on the radial aspect, with incision down to the fascia of the forearm. The cephalic vein is identified and spared if it will be included in the flap. Dissection proceeds centrally until the septum containing the radial artery is found. The surgeon will find the superficial radial nerve branches a helpful landmark. The plane of dissection should be above the nerve branches to spare them and preserve distal sensitivity.

**Fig. 8D-4** A, An incision is made along the proximal radial margin of the flap, including the deep fascia. Branches of the cephalic vein are identified and protected. The brachioradialis muscle is retracted toward the radius, exposing the radial artery, its venae comitantes, and the superficial branch of the radial nerve, which lies more laterally in the lateral intermuscular septum.

Next, the ulnar side of the flap is incised and again elevated just under the fascia. Care is taken to keep the peritenon on tendons in the area so that a skin graft closure is possible. Again, the septum containing the radial artery is approached.

**Fig. 8D-4** B, Dissection continues in an ulnar to a radial direction beneath the deep fascia until the lateral intermuscular septum on the lateral aspect of the flexor carpi radialis is located. Dissection is then carried between the flexor carpi radialis muscle and the lateral intermuscular septum to the anterior surface of the radius. The radial artery is visible within the lateral intermuscular septum.
The distal incision is made and the deeper fascia of the wrist is opened, exposing the radial artery and its venae comitantes. These are divided.

The upper border of the flap is incised, with care taken to preserve the cephalic vein. The lateral antebrachial cutaneous nerve is also identified at this point running with the cephalic vein and should be spared if a sensate flap is desired. Once the flap is dissected proximally, perforating branches from the radial artery to the brachioradialis muscle are ligated. Once the flap is elevated to its proximal margin, dissection of the cephalic vein is performed proximally. The skin is opened in an area overlying the radial artery and cephalic vein so both can be easily accessed. Once the vein has been dissected for the appropriate length, deeper dissection can be performed, isolating the radial artery and its venae comitantes.
FLAP VARIANTS

- Reverse radial forearm flap
- Adipocutaneous flap
- Fascial flap
- Osteofasciocutaneous flap
- Myocutaneous flap
- Tendinocutaneous flap
- Vascularized nerve flap (superficial radial nerve)
- Flow-through flap

Reverse Radial Forearm Flap
The reverse variant is based on retrograde flow through the deep palmar arch and associated venae comitantes. To produce appropriate arc of rotation, the flap design is placed more proximally in the forearm. One should be careful not to place the design too proximal as there are fewer perforators from the radial artery at this level because of the arteries’ depth. Also, venous outflow from this flap is based on reversed flow in the veins, and often the flap is initially congested. This reversed flow may lead to some flap loss. Occasionally, extra cephalic vein is harvested with the flap proximally and is used to decompress the venous system, with vascular anastomosis at the recipient site. Incisions are made along the upper proximal and distal borders of the flap down through fascia. The radial vessel is identified, and perforators emanating from the vessel to the skin paddle are preserved. An incision must then be made distally over the course of the radial artery identified by Doppler examination. The radial artery and associated venae comitantes are then mobilized along with the flap from proximal to distal, the rotation point being the level of the wrist.

Design of reserve flap

Fig. 8D-5
Adipocutaneous Flap (Suprafascial Harvest)
Fascia of the arm may be preserved and elevation of the flap limited to the skin and subcutaneous tissues. Care must be taken to include perforators of the radial artery and flap vascularity will not be compromised. The advantage of this flap would be to maintain fascia over the tendons of the arm to prevent adhesion formation and to maximize a skin graft take by not attempting to graft peritenon.

Fascial Flap
When skin is not required and there is a desire to improve the donor site skin graft deformity, a radial forearm flap can be harvested as a fascia-only flap. This is advantageous when thin fascia is required for reconstructive purposes, such as tendon reconstruction. An incision is made along the central axis of the radial vessel and skin and subcutaneous tissues are elevated along each side of the area of flap to be harvested. The fascia can then be incised, and flap elevation proceeds as described for the standard flap.

Osteofasciocutaneous Flap
A segment of radial bone may be included with the radial forearm flap. A segment of bone 10 cm long, which encompasses no more than 30% of the cross-section of the radius, may be harvested. A keel-shaped bone harvest is recommended to reduce the possibility of radial fracture.

Vascularized bone territory

Fig. 8D-6
Flap elevation is similar to that described for the standard flap until the radial vessel is reached on either side of the septum. Retraction of the brachioradialis and the flexor carpi radialis muscles exposes the muscle bellies of the flexor pollicis longus and pronator quadratus. The area of bone to be harvested is marked, and the muscle bellies are then divided down and through the periosteum. Bone cuts can be made with a saw for bony harvest.

Fig. 8D-7  An osseous segment of radius may be included with the fasciocutaneous flap. A, The skin flap design is similar to that of the fasciocutaneous flap. B, At approximately 1 to 1.5 cm medial to the lateral intermuscular septum, the bellies of the pronator quadratus muscle and flexor pollicis longus muscles are identified and the perforators of the radial artery to the skin are noted and spared. C, The skin incision is extended proximally to dissect the pedicle and the cephalic vein proximally.
Myocutaneous Flap
The brachioradialis and flexor carpi radialis muscles can be harvested with the flap to include muscle. For reconstructive purposes one must visualize the perforating branches to these muscles if attempting to keep them vascularized with the flap. Of the two, the brachioradialis is the more commonly harvested, because there are fewer functional sequelae (see Clinical Applications in Section 8B).

Tendinocutaneous Flap
The palmaris longus tendon and tendon of the flexor carpi radialis can be harvested with the flap as vascularized tendon grafts. These are often helpful in reconstruction of the eyelid, cheek, and lip in the head and neck, as well as reconstruction of the hand and foot. Again, small vascular connections between the radial artery and these tendons must be maintained if a truly vascularized structure is desired (see Fig. 8D-13).
Vascularized Nerve Flap (Superficial Radial Nerve)
The superficial branch of the radial nerve may be harvested based on the radial vessels as a vascularized nerve graft. This can be the nerve alone or in combination with the overlying skin paddle.

Flow-Through Flap
Because of the large caliber of the radial vessels, the radial forearm flap can be used both for coverage and for revascularization of a dysvascular part of the anatomy. This distal vessel can also provide a recipient site for a second free flap. This is most commonly seen for revascularization of the extremities and for multiple free flap reconstruction in the head and neck.

ARC OF ROTATION

Standard, Adipocutaneous, and Fascial Flaps
The arc of rotation includes anterior and posterior forearm, elbow, and upper arm.

Reverse Flap
Based on retrograde flow through the deep palmar arch and associated venae comitantes, the rotation point of this flap is at the level of the wrist and will allow coverage of defects of the palm and the dorsal surface of the hand and thumb.
FLAP TRANSFER

Standard Flap
Flaps are transferred proximally through direct incision connecting the recipient and donor sites or through a subcutaneous tunnel. Care must be taken to prevent compression within the subcutaneous tunnel. Postoperative splinting is also critical for preventing compression of the pedicle for uses that cross the elbow joint.

Reverse Flap
The reverse flap is transposed directly to the hand for reconstruction. Management of the exposed pedicle must be painstaking; it can be buried under mobilized skin for skin coverage. Sometimes skin grafting is required because of the bulk of the pedicle tissues as they cross the thin wrist, which does not tolerate subcutaneous tunnels. In this case, secondary revisions may be necessary.

Free Flap
A free flap is transferred using standard microvascular principles, avoiding tension on the pedicle. With long radial artery and cephalic vein pedicles, one must maintain proper orientation of the pedicles throughout. This can be accomplished by marking the artery and vein before division and using this visual guide to prevent kinking of the flap at inset.

FLAP INSET

Pedicle Flap
It is essential to inset the flap without tension. In a reverse flap, where congestion may occur, a temporary inset is sometimes appropriate to prevent excessive tension on an already compromised flap. Secondary closure can be performed in 48 hours or later.

Free Flap
Insetting a free flap requires careful placement of the pedicle. For bone-containing flaps, the osteosynthesis is often performed first to prevent tension or damage to the vessels after reanastomosis. The surgeon must ensure that there is no tension on the closure of the flap.

DONOR SITE CLOSURE
Primary closure is possible only for flaps less than 4 cm in diameter. Although it is technically possible to achieve skin closure, the amount of compression of the arm, which is now relying only on the ulnar vessel, can be limiting and will have a tourniquet-like effect, especially with postoperative swelling. In most cases a skin graft is required for donor site closure.
CLINICAL APPLICATIONS
This 26-year-old man had a crush injury to his foot; the wound became chronic, and he had nerve pain. At exploration and debridement, dead bone was identified and resected, and a neuroma in continuity was resected and repaired.

Fig. 8D-11  A, Chronic open wound with exposed dead bone. Dots show the planned skin resection. B, A radial forearm free flap (6 by 9 cm) was used to resurface the defect with microscopic anastomosis to the dorsalis pedis vessels. C, Side-by-side donor and recipient sites at 4 months postoperatively. (Case supplied by MRZ.)
This 43-year-old woman had a squamous cell carcinoma of the tongue. A hemiglossectomy was performed. Although much of the defect could have been closed or allowed to heal secondarily, the addition of a radial forearm flap improved tongue mobility and limited distortion from secondary healing and scarring.

Fig. 8D-12  A, After completion of the right hemiglossectomy with a lymph node dissection on the right side of the neck. B, A 3 by 7 cm radial forearm flap was elevated with the lateral antebrachial cutaneous nerve for reinnervation of the flap. C, After flap inset and arterial anastomosis to the facial artery and venous anastomosis between the vena comitans and a branch of the internal jugular vein. The lateral antebrachial cutaneous (LABC) nerve was anastomosed to the transected lingual nerve. D, The result is seen 4 months postoperatively with the patient in repose, and E, with protrusion of the tongue. F, The donor site 4 months after primary closure. (Case supplied by MRZ.)
This 61-year-old had a squamous cell carcinoma of the lower lip. The large defect was reconstructed with a radial forearm flap, supported by vascularized fascia. Microstomia was avoided by adding tissue to the area.

![Fig. 8D-13](image)

**A**, Preoperative view of the lesion. **B**, The resulting 80% full-thickness defect of the lower lip. **C**, A tendinocutaneous flap was planned using the palmaris longus, which was not present. Instead, the flexor carpi radialis tendon was harvested to support the skin paddle which would line the outside and inside of the lower lip. The LABC nerve was also harvested with the flap for reinnervation. **D**, The flap in position for anastomosis of the vessels in the neck, tendon into the commissure, and nerve to the mental nerve stump. **E**, Immediately after inset.
Fig. 8D-13  F, Flap at 1 year postoperatively, ready for revision. The patient required an aggressive debulking and a reconstruction of the vermilion. G, The flap was debulked directly, and quilting sutures were placed. A facial artery myomucosal (FAMM) flap was thought to be too bulky for vermilion reconstruction, so a free buccal graft was harvested. H, Immediately after debulking and buccal graft placement. I, Three months after debulking and grafting, the patient is seen in repose and J, with an open mouth. Microstomia was avoided by adding the radial forearm flap. Lip competence was ensured by using the vascularized tendon graft. The aesthetic of the vermilion was reestablished with a simple buccal graft. (Case supplied by MRZ.)
This 35-year-old man sustained a gunshot wound to his palm that resulted in loss of the fourth metacarpal and produced a large dorsal exit wound. The affected area was debrided and initially stabilized with an external fixator and a methylmethacrylate spacer for staged bony reconstruction. The patient had a normal Allen’s test, and a reverse radial forearm flap was used for soft tissue coverage.

Fig. 8D-14  A, The dorsal wound after debridement and external fixator pin placement. B, Hand radiograph showing bony loss. C, Planned reverse radial forearm flap, centered over the radial artery. D, The flap was elevated and transposed through a short subcutaneous tunnel. It is not unusual to have some venous congestion after transposition. E, The patient had cancellous bone grafting at 2 months postoperatively and is seen 6 months later (dorsal view) and F, (volar view) without any other revisions. (Case supplied by MRZ.)
This 45-year-old man had undergone a maxillectomy for squamous cell carcinoma. A radial forearm flap was planned for bony reconstruction as well as palate and nasal floor reconstruction.

**Fig. 8D-15**  
A, The preoperative defect, with loss of midface support and no separation between mouth and nasal cavity.  
B, The radial forearm flap with cephalic vein and vascular pedicle isolated, attached skin paddle, and exposed radius ready for osteotomy (dashed line).  
C, After bilateral bone inset to the neighboring maxilla.  
D, The skin paddle was first used to reconstruct the palate by suturing to the remaining mobile soft palate. The skin was then wrapped around the bone and used to line the nasal floor. The midportion of the flap was deepithelialized and the lip segment was inset.  
E, At 4 weeks postoperatively, the intraoral view shows that the flap is viable and growing hair.  
F, A lateral skull radiograph demonstrates the bony reconstruction holding out the soft tissues of the maxilla at proper length, preventing the common postmaxillectomy appearance of a retruded midface. (Case supplied by MRZ.)
This 47-year-old woman had a maxillary tumor excised, leaving a large skin defect. There was also a small CSF leak and open communication with the oropharynx. A radial forearm flap was chosen with multiple skin paddles for this complex reconstruction as well as some brachioradialis muscle for repair of the CSF leak and soft tissue fill.

**Fig. 8D-16**  
A, The defect after resection. The area of CSF leak was in the posterior orbit after exenteration. The facial vessels were exposed in the neck as the recipient site. B, The flap was elevated. The larger skin paddle was for external skin coverage, the smaller for palatal repair. The long vascular pedicle will reach the neck without vein grafts or A-V loop. The cephalic vein was taken with the flap as well. C, The undersurface of the flap demonstrating the brachioradialis muscle carried with the flap based on perforators from the radial artery. D, After flap inset. The muscle nicely covered the area of CSF leak, which healed uneventfully. E, Two months postoperatively, the flap has settled nicely, which is desirable if a prosthesis will ultimately be worn. F, Final result with an external prosthesis in place.  
(Case supplied by MRZ.)
This 42-year-old man had a squamous cell carcinoma of the upper lip; he underwent resection and reconstruction with a radial forearm free flap, supported with a vascularized palmaris longus tendon. This was a functional reconstruction, but not an aesthetic one. As a secondary procedure, a mustache reconstruction was planned with a scalp flap based on the superficial temporal system.

**Fig. 8D-17**  
A, Preoperative view of the lip. Skin taken from areas distant to the face are often a poor color and texture match. Mustache reconstruction is a good camouflage procedure, although this is obviously not possible in women, who can use concealing cosmetics.  
B, The planned flap. Allowance was made for loss of some arc of rotation because of the rotation and placement through a tunnel. A Doppler probe localized the vessels, which were then marked. It is critical to plan the flap with hair growth in the desired direction. The flap was first incised, partially elevated, and delayed.  
C, Two weeks after delay. The flap was passed through a subcutaneous plane. The outer skin of the lip reconstruction was resected and replaced with the scalp flap.  
D, The flap 1 week postoperatively and  
E, 4 months postoperatively the upper lip color maintained a pink hue as a result of intraoral exposure over time, and no graft was required. (Case supplied by MRZ.)
This 29-year-old woman presented with loss of her nasal columella and vestibular lining.

**Fig. 8D-18**  
A and B, The patient is seen preoperatively.  
C, A template was marked for the flap to restore the nasal floor lining, vestibule, and columella. The flap is oriented so that the radial vascular pedicle lies directly beneath the posterior edge of the floor element.  
D and E, The flap was delayed to selectively redirect dermal perfusion from the posterior edge of the floor element to the vestibular and columellar elements.
Fig. 8D-18  F, The nasal site was prepared by excision of all diseased and scarred nasal lining. Access to the nasal lining was via the intraoral approach through a labial gingival sulcus incision. G, Before transfer, the component elements of the flap were assembled anatomically. The flap was then vascularized to the facial artery and vein. H, Immediate postoperative view of the flap inset. Additional contouring procedures were required at 3 and 6 months postoperatively. I and J, The patient is shown 13 months after microsurgical transfer of the forearm flap. (Case courtesy Robert L. Walton, MD.)
This 39-year-old man had a traumatic loss of the distal portion of his nose, including the vestibule, left nostril floor, and caudal septum/columella.

Fig. 8D-19  A and B, The patient is seen preoperatively. C, A two-island radial forearm free flap was planned for restoration of the nasal lining. D, After microsurgical transfer, the flap elements were assembled anatomically and inset into the defect.
Fig. 8D-19  
E and F, After inset of the radial forearm flap islands, the elements were braced with small matchstick grafts of cadaver allograft cartilage to prevent shrinkage in the interim between lining restoration and definitive coverage with the forehead flap. The undersurface of the vestibular flap element was temporarily covered with a full-thickness skin graft, which was placed directly over the cartilage allografts. G and H, The patient is shown 18 months after a forehead flap procedure (performed by Dr. G. Burget) and placement of supporting autologous rib cartilage grafts for definitive structural support. A free anterior lateral thigh flap was also transferred to the patient’s left cheek to restore soft tissue volume. (Case courtesy Robert L. Walton, MD.)
This 58-year-old man presented with composite nasal/maxillary defect following surgical excision of a recurrent basal cell carcinoma, followed by radiation therapy.

**Fig. 8D-20**  
A and B, The patient is seen preoperatively. C and D, The initial approach to reconstruction was restoration of the nasal vestibular lining, left nostril floor, and adjacent cheek, composing the nasal base. A two-island flap based on the volar forearm was designed to address the missing soft tissue elements. After elevation, the flap was debulked and then transferred to the facial site, where vascular repairs were made to the recipient facial artery and vein. E and F, Immediate postoperative view of transferred radial forearm flap. The flap islands were articulated anatomically and the exposed vestibular element undersurface was closed with a full-thickness skin graft.
Fig. 8D-20  G and H, The healed lining flaps are shown 8 weeks postoperatively. I, Ten weeks after microsurgical transfer, the patient returned for the second stage of the reconstruction. The skin graft covering the vestibular element was removed and the flap was debulked to the level of the dermis. J, After debulking, autologous costal cartilage grafts were placed to support the dorsum, tip, ala, and nasal side wall. K-M, A paramedian forehead flap was then placed to provide external nasal cover. The patient will return in 6 to 8 weeks for debulking of the forehead flap and selective placement of cartilage grafts to achieve the desired final shape and contour before division of the pedicle. (Case courtesy Robert L. Walton, MD.)
Pearls and Pitfalls

- Good perfusion to the hand must be ensured by performing a preoperative Allen’s test before deciding to use a radial forearm flap.
- Harvesting bone in elderly patients and women should be avoided, because the incidence of fracture is much higher in these populations.
- To help prevent radial fracture, plating of the radius and casting of the forearm including the elbow should be considered for 3 to 5 weeks postoperatively when bone is harvested.
- Paresthesia and dysesthesia distal to the flap can be avoided by carefully preserving the branches of the radial sensory nerve during flap elevation.
- The flap is advantageous because it allows a two-team reconstruction, especially in head and neck surgery.
- The radial artery is rarely involved with any systemic atherosclerosis that may be present.
- There is limited postoperative pain and immobilization from harvesting this flap.
- The biggest disadvantage of the radial forearm flap is the conspicuous donor deformity of the forearm, especially in women.

EXPERT COMMENTARY
Robert L. Walton

Indications
I have found the radial forearm flap to be very useful for reconstruction of a variety of facial/nasal defects and it is particularly useful in conditions that require multi-island fabrications.

Advantages and Limitations
The radial forearm flap is a very robust flap with consistent anatomy. Elevation is straightforward. Limitations of the flap lie primarily in its relatively small bulk and size. Donor site scarring can be a problem, especially in women.

Anatomic Considerations
A critical issue in the use of the radial forearm flap is prior catheterization of the radial artery. I have had two cases in which partial flap loss occurred in flaps harvested from forearms that previously underwent radial artery arterial line catheterization. Despite palpable pulses and a positive Allen’s test, these flaps exhibited compromised perfusion after the flap was elevated. I suspect that the arterial catheterization may have resulted in thrombosis of the small radial arterial perforators into the overlying subcutaneous tissue and skin.

For complex flap shapes, I have found that delay of the radial forearm flap is advantageous for augmenting dermal perfusion and do this routinely 10 to 14 days before flap transfer. In a case a number of years ago, we performed an immediate external cover flap using a suprafascial radial forearm flap in a 16-year-old girl. The alar element of the flap that lay
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over the ulnar side of the volar forearm necrosed following transfer, necessitating use of a second free flap from the abdomen. With surgical delay, I have not observed flap necrosis in any patient, including those with flaps having very complex configurations.

I think the primary venous drainage of the flap is through the paired venae comitantes coursing with the radial artery, and this has been recently verified by Selber et al. The cephalic vein is a secondary conduit, as evidenced by the sparse branching in the volar forearm. As noted in the excellent article by Gottlieb et al, the venae comitantes coalesce into a single vein at the level of the brachial artery bifurcation. The profundus cubitalis vein (vena anastomotica) connects this coalesced (deep) vein to the cephalic vein at the level of the cubital fossa. Both the deep and superficial venous systems are drained via one large anastomosis, situated proximal to the profundus cubitalis interconnection.

Advantages of this technique include the following: (1) venous drainage of the radial artery forearm free flap is improved; (2) the venous anastomosis is rendered technically easier because of its larger size; and (3) the technique offers greater versatility in designing the venous portion of the vascular pedicle. Deep systems join in the proximal forearm, allowing for single outflow vessel anastomosis. This configuration is reserved for large flaps that wrap the radial forearm distally and extend the greater length of the forearm to the wrist.

Recommendations

Planning

It is preferable to harvest the flap from the nondominant upper extremity. Use of the Allen’s test is important to ensure adequate inflow into the hand from the ulnar artery (although I have not encountered a case in which a radial forearm flap could not be used because perfusion was inadequate). The flap is centered over the radial artery whenever possible, depending on flap size, except in cases of surgical delay, where flap design is such that the radial artery and its perforators are aligned to the edge of the flap, “out of harm’s way,” to facilitate ease of inset and to avoid pedicle compression when using bone or cartilage grafts. With multiple islands, I have found it helpful to create templates of foil connected by Steri-Strips to mimic the radial pedicle. The foil templates are then articulated in space to ensure correct size and configuration and to allow easy positioning without kinking of the pedicle. The old adage “measure twice, cut once” is quite apropos in these situations.

Technique

As noted earlier, I do not routinely use the cephalic vein in flap design unless the flap is inordinately large such as is encountered in penile reconstruction. Before making the skin incision, I identify the brachioradialis and flexor carpi radialis tendons at the volar wrist and trace these proximally. These structures will form the boundaries of the “no-fly zone” defining the traverse of the radial pedicle and its perforators to the overlying skin paddle. In most cases I prefer to harvest the flap in the suprafascial plane, preserving the deep fascia for coverage of the volar tendons and nerves. This results in less donor site morbidity and allows selective thinning of the flap as necessary for the reconstruction at hand.

When one is harvesting multiple islands, magnification (loupe or operating microscope) should be used to identify the radial perforators to each island. After the islands have been dissected, care must be exercised to protect each island from shear or twisting forces that might injure the perforating vessels.

Continued
The thickness of this flap should not be underestimated despite its apparent thinness in situ. This is especially relevant when transferring the flap to the face for use in nasal lining reconstruction or external nasal cover. Direct debulking of the flap before transfer can be effectively accomplished by using operative magnification to visualize the fat globules, allowing for their lysis and direct suction removal with care to avoid injury to the radial pedicle perforators and the subdermal vascular plexus. In obese patients, pretransfer debulking/delay of the flap is essential for avoiding the typical “meatball” configurations that result from transfer of the whole thickness of the flap. In certain reconstructions in which the flap is tubed for reconstruction of the columella, it is important not to coapt the opposing edges under tension, because this will compromise the blood flow. In these cases, it is helpful to apply a small full-thickness skin graft to the folded edges of the flap to ease the tension. These grafts do quite well if adequate hemostasis is achieved before application of the skin graft.

I rarely advocate use of the reverse configuration of the radial forearm flap, since it frequently leads to a “sick” flap, with venous congestion and unreliable perfusion of the skin island. In these situations, a straightforward antegrade radial forearm free flap vascularized to the radial or ulnar pedicle foregoes the adverse risks inherent to the reverse radial forearm flap.

Similarly, use of the osteofasciocutaneous radial forearm flap makes little sense, because the procedure carries considerable risk for radius fracture, and the donor defect has considerable morbidity. In my opinion, this flap design totally disregards the importance of the forearm/upper extremity for function and should be abandoned.

Closure of the radial forearm donor site is generally straightforward. I routinely employ a full-thickness skin graft harvested from the inguinal region. A full-thickness skin graft provides very stable coverage for the distal volar forearm donor site; it is pliable, exhibits minimal contraction, and is aesthetically quite acceptable. A template of the forearm defect is transferred to the inguinal region, where it is incorporated within the confines of an ellipse, the longitudinal axis of which is aligned with the inguinal fold. For large defects, the graft may need to be applied as articulated segments derived from the confines of the ellipse. The graft is inset with 4–0 silk sutures that are used to secure a sponge stent.

**Postoperative Care**

After application of the stent dressing, the forearm and hand are wrapped in a light compression bandage composed of Kerlix fluffs, Reston foam, cling wrap, and an Ace wrap secured with staples. The bandage is kept in place for 1 week. (I do not use arm slings, since these tend to produce shoulder stiffness, especially in older patients. I have the patient carry the bandaged arm upright, and encourage overhead stretching on postoperative day 1). The stent dressing is removed and graft take is assessed at 1 week. The graft is redressed with a petrolatum dressing and a light gauze wrap and Ace bandage. At 2 weeks postoperatively, the sutures are removed and moisturizing creams are applied. The forearm is kept wrapped with an ace bandage by the patient for the next 3 months to stifle hypertrophic scarring and promote contouring of the forearm donor site.

The flap reaches maximal swelling at 48 hours. Close observation must be maintained to ensure that this swelling does not interfere with flap perfusion, especially if multiple islands are used. If there is any concern about flap perfusion as the swelling ensues, release of several inset sutures may be all that is necessary to relieve the compromised perfusion. These can be replaced once the swelling subsides, usually within 3 to 4 days. If the flap is transferred to the
face, care must be taken to avoid the use of cool mist face masks or blow-by oxygenation as these may result in excessive cooling of the flap, vasospasm, and thrombosis. To avoid this complication, the surgeon should insist on the use of warm (steam) humidification for all oxygenation adjuncts and be certain to check this to ensure that no cool mist is contacting the flap.

Complications
Complications inherent to the radial forearm flap are few; this is a very robust flap with large-caliber vessels and an infinite assortment of configurations and applications. As noted earlier, one must be wary of using the radial forearm flap if prior catheterization of the radial artery has been performed, even if the Allen’s test demonstrates robust perfusion via both radial and ulnar systems. When using the flap around hardware, the surgeon must be aware that hardware can very quickly occlude the pedicle, especially as the flap swells. In these cases, judicious placement of the pedicle away from any restricting hardware or bone graft will be good insurance against middle of the night phone calls. If the pedicle is oriented toward the edge of the flap, as in nasal reconstruction, it is often helpful to delay the flap to ensure adequate perfusion of the skin island.

Take-Away Messages
This is a very reliable flap. Careful planning and execution will result in successful reconstruction.

References

Bibliography With Key Annotations

The authors reviewed their experience with 100 radial artery free flap donor sites. Sixty-seven patients required skin grafting, 33 patients underwent direct closure of their defects, and 17 patients had compound osteocutaneous flaps. Wound healing was a significant problem in patients who had skin grafts and harvested radial bone. Fracture of the radius occurred in 4 of 17 of those patients and represented the most significant postoperative morbidity. In 12 patients the radial artery was reconstructed, but only six of these vessels were patent at the time of review. The authors reported that the donor site was relatively pain free. The aesthetic result was more acceptable in men than women, and was even less acceptable in patients who had a radial fracture. Based on this experience, the authors no longer recommended routine reconstruction of the radial artery. The donor defect was closed directly when possible, including an ulnar artery transposition flap if necessary. The osteotomy to harvest the bone was made in a “boat shape” rather than right-angle bone cuts. These changes significantly improved the donor site results and minimized complications.

This was a retrospective analysis of complications in the donor limb in 27 patients who underwent forearm flap procedures. Of 13 patients whose flaps contained bone, four had fractures of the radius. This led to a 50% loss of power of grip and pinch and limited pronation and supination. Cold intolerance and clinical signs of hand ischemia were not reported. Of 12 radial arteries reconstructed, only seven remained patent.


This was an initial report of seven cases of penile reconstruction with a radial forearm flap. A “tube within a tube” was created to reconstruct the urethra and the shaft of the penis with this neurosensory flap. A segment of rib cartilage was used to provide firmness for the reconstructed penis. In two patients the medial cutaneous nerve of the forearm was included to provide sensation. The authors emphasized that the less-hair-bearing ulnar border of the flap should be used for the urethral portion of the reconstruction.


The authors shared their experience treating four patients with recalcitrant oronasal fistulas after all other attempts at closure had failed. In three patients one-stage reconstruction was successful using the radial forearm free flap. In a fourth patient a secondary procedure was necessary for complete fistula closure. All patients had excellent results, with improved speech and no nasal regurgitation. The authors pointed out that the radial forearm flap, with its extremely long pedicle and large vascular pedicle lumen diameter, provided a flap with thin, hairless skin ideally suited for palatal closure in patients with difficult or recalcitrant fistulas.


This report described six patients who underwent patch esophagoplasty with a free radial forearm flap to relieve focal strictures in the cervical esophagus. The authors enumerated the advantages of this method, which produced less morbidity and a superior aesthetic result compared with other techniques, including pedicle and myocutaneous flaps.


In this case report the free radial forearm flap was transferred as an innervated free flap to resurface the entire weight-bearing plantar surface of the foot. At the 10-month follow-up protective sensation was present on the lateral two thirds of the plantar surface of the flap, corresponding to the distribution of the medial antebrachial cutaneous nerve.


The authors investigated the blood supply to the radius through fresh cadaver injection studies of the radial artery. They concluded that a segment of the lateral part of the distal radius, usually incorporated with the radial forearm flap as a compound osteocutaneous flap, was supplied through two fascioperiosteal branches of the radial artery and a myoperiosteal plexus at the site of attachment of the flexor pollicis longus muscle.

There are problems associated with delayed wound healing when the donor site of the radial forearm is skin grafted. The authors described an ulnar fasciocutaneous flap that is advanced distally to cover the radial forearm donor site, and the donor defect resulting from the advancement of the ulnar flap closed in a V-Y fashion. This method of closure had several disadvantages. It is limited to flaps with dimensions of 8 by 4 cm or less. A V-shaped incision in the proximal forearm denerves the skin of the volar aspect of the forearm; however, the authors reported that this was not a problem. Because the incision may also interrupt the lymphatic drainage of the ulnar flap, gentle flap compression with bandages was recommended postoperatively.


The authors investigated the venous drainage of standard and distally based radial artery island flaps. Radiographic studies were performed on 12 upper limbs after barium sulfate injection. Injection of one of the radial artery vena comitans in retrograde fashion resulted in perfusion of both of the venae comitantes through cross-communicating branches in a step-ladder fashion. Histologic studies demonstrated valves in both the venae comitantes and the vessels lying in the mesentery between the venae comitantes. Retrograde flow of barium sulfate in the cephalic vein was obstructed. They postulated that venous drainage in the retrograde or distally based flap improves gradually as the venous valves become incompetent as a result of high venous pressure.


The authors described their modification of the “cricket bat” concept of phalloplasty in which a longitudinal and transverse rotation of the linear forearm tissues was used to create the phallus. A coronoplasty was added to complete the reconstruction.


The authors presented their experience with 14 radial forearm flaps for upper extremity defects. Eleven of these flaps were reverse-flow flaps, and two were transferred on an extracorporeal vascular pedicle. If there was not enough space to accommodate the vascular pedicle, as under the palmar skin, or if the flap would not reach the defect when the pedicle was buried, the authors simply inset the flap and wrapped the pedicle vessels with a skin graft. They called this an “extracorporeal pedicle.” This pedicle was excised at 3 weeks. A variety of traumatic injuries of the upper extremity were reconstructed with the flap.


The author advocated the use of tissue expanders to improve the radial forearm flap donor site. Tissue expanders were placed immediately at the time of flap harvest in 9 of 10 patients. A 40% minor complication rate was reported. These included wound dehiscence, expander puncture, valve exposure, and postadvancement wound dehiscence. This modification did not result in significant improvement of the donor site defect.


In this very interesting flap modification, two separate flaps were harvested from the same forearm and then transferred to bilateral foot defects.

The authors reported their experience with five patients in whom a radial forearm flap was transferred to reconstruct the Achilles' insertion, heel, instep, forefoot, and dorsum of the foot. They emphasized the quality of the results in terms of restoration of normal foot contour, durability, and excellent aesthetic appearance. The advantages of the flap included its long pedicle, potential sensory innervation, and appropriate thickness for foot reconstruction.


The authors summarized their experience with 12 patients in whom the pharynx and cervical esophagus were reconstructed with a tubed radial forearm free flap. They emphasized the advantages of this method of reconstruction over the use of the jejunum, especially because it eliminated the need for an intraabdominal procedure. Of the nine patients who underwent circumferential reconstruction, five developed fistulas and two developed strictures at the esophageal anastomosis.


The authors examined the blood supply to the skin and bones of the forearm in 10 upper limbs from fresh cadavers. They were perfused with a radiopaque lead-oxide mixture. A total of 200 muscles were also studied. The specimens were dissected, the vessels were tagged with metal clips and radiographed, and branches were mapped with colored pins corresponding to the respective source arteries. The bones were replaced with radiolucent balloons to facilitate visualization of the forearm vasculature. Then the muscles were removed one by one from the muscle mass and radiographed again. Angiosomes in the forearm provided by the brachial, radial, ulnar, and interosseous arteries could then be defined. Similarly, the contribution from each angiosome to the skin, each muscle, and the radius and ulna was identified, and the territories were color-coded to correspond with source arteries. Connections between adjacent angiosomes mostly occurred within tissues, not between them. The source arteries from at least two angiosomes supplied skin, bones, and most muscles. This anastomotic pathway becomes extremely important if a source artery is interrupted by disease or trauma. Several muscles were nourished within one angiosome, explaining the variety of responses to interrupted circulation, as with Volkmann's ischemic contracture. This study presented information to help design flaps from the forearm for local or free transfer.


To minimize donor site complications after harvesting a forearm flap, the author advocated harvesting it as a fascial flap to preserve the forearm skin. He presented eight cases in which the free fascial flap was transferred as a free flap for lower extremity reconstruction and then covered with a skin graft. The advantages of this fascial flap over other fascial flaps were enumerated. These included a longer vascular pedicle, a larger fascial donor area, and the possibility of combining fascia with tendon and bone.


A distally based forearm island flap was performed in 12 patients with soft tissue defects of the hand. The skin flap was supplied by the perforators of the distal radial artery, and the pivot point of its subcutaneous pedicle was approximately 2 to 4 cm above the radial styloid process. Eight skin flaps, two adipofascial flaps, and two sensate flaps were performed. The flaps ranged from 6 by 4 cm to 14 by 6 cm. The donor site wound was closed primarily in five patients. Advantages of the flap were discussed.


The authors shared their experience performing a radial forearm flap in a patient with a positive Allen test preoperatively. Acute ischemia of the hand resulted, and circulation was reestablished by a vein graft. The importance of ensuring hand circulation after harvesting this flap was emphasized.

This article discussed the usefulness of the radial artery perforator–based adipofascial flap for resurfacing dorsal hand defects. It is a distally based septocutaneous flap supplied by the dorsal superficial branch of the radial artery. The numerous advantages of the flap were presented.


The radial forearm osteocutaneous perforator flap comprises vascularized radial bone and superficial adiposal tissue, nourished by a single perforator of the radial artery. The authors transferred this flap in a one-stage reconstruction in a patient with total nasal loss.


The authors studied the venous drainage on venograms in three patients who had undergone reverse forearm flap reconstruction. They described two patterns of venous drainage: the “crossover pattern” of the communicating branches between the two venae comitantes and the “bypass pattern” of the collateral branches of each vein. These provided effective retrograde venous drainage. The crossover pattern allowed communication between the two venae comitantes, thereby establishing a method for bypassing the valves in each of the vena comitans. Drainage through small collateral branches of each vein effectively bypassed the valves in the same vein. These crossover and bypass patterns explained the reverse drainage of venous blood even if the valves in the veins were intact.


The author presented two cases in which the ankle and heel area were resurfaced with innervated preexpanded radial flaps. The advantages of preexpansion included minimizing the donor defect, which was closed directly, and the potential for enlarging the size of the flap for transfer. However, the major advantage of preexpansion was that a large flap could be harvested when the small amount of remaining forearm skin was not suitable for secondary expansion to minimize the donor defect.


The author presented his experience with the free radial forearm flap in 16 patients. To minimize complications associated with skin grafting the donor site, he applied the graft with the wrist extended and the gutter between the flexor carpi radialis and brachioradialis carefully packed to ensure adequate contact between the graft and underlying tendons and muscles. The extremity was then immobilized in a plaster cast for at least 10 days. The graft was inspected and the forearm splinted for an additional 10 days to prevent tearing of the skin graft by underlying flexor carpi radialis tendon motion. The author emphasized that, with the wrist extended, the flexor carpi radialis tendon was flat on the flexor pollicis longus, and the depth of the gutter and thus the dead space were minimized. Full wrist extension was preserved by grafting with the wrist in extension.


A distally based reverse-flow radial forearm flap, including the palmaris longus tendon and part of the tendinous portion of the brachial radialis, was used to provide coverage for the dorsum of the hand and to reconstruct extensor tendons that had been lost as a result of the injury.


Four patients underwent total lip and chin reconstruction. In three patients a composite flap, including the radial forearm and palmaris longus, were used to reconstruct the chin and lip. The cut end of the palmaris longus tendon was sutured to the modiolaris bilaterally. This modification led to aesthetically acceptable reconstructions with this innervated flap, including the palmaris longus tendon.
and speech were good, and there were no problems with drooling. With this excellent modification, reconstructive surgeons can reestablish continence of the oral sphincter.


The authors presented their technique of preserving the radial artery in a free transfer of the radial forearm flap. Their 42-year-old patient had undergone excision of a mandibular osteosarcoma and developed neck contracture after subsequent radiation therapy. They elevated the flap as a distal row perforator-based fasciocutaneous flap, including a short segment of the radial artery in the inverted-T-shaped arterial pedicle. The cephalic vein, with accompanying veins of the radial artery that were left behind, provided venous outflow. The donor radial artery was repaired primarily. The superior thyroid artery and one limb of the arterial pedicle were anastomosed end to end (the other limb was ligated). The cephalic vein and the external jugular vein were anastomosed. The result was satisfactory, and the radial artery was patent long after surgery (Allen’s test and Doppler examination).


The authors reviewed their extensive experience performing the radial forearm flap in 60 consecutive patients who had had intraoral reconstruction. They reported six microvascular failures. Thirty-nine patients had early postoperative radiation therapy, without flap viability or wound-healing problem. The authors emphasized the need for a preoperative Allen test before flap reconstruction. In their first 10 patients the radial artery was reconstructed with a reversed vein graft. However, in the last 10 patients arterial reconstruction was performed only in exceptional circumstances. Dividing the radial artery did not harm any patients, though this was a concern preoperatively. Direct closure of the donor defect was possible in seven patients, with no wound-healing complications. The rest had skin grafts, and some had difficulty with graft take. Exposure of the tendon of flexor carpi radialis was reported. This was thought to be related to failure to preserve the peritenon. Remarkably, only one patient required a second skin-graft procedure to obtain complete closure of the donor area. For patients in whom the radius is harvested, the authors recommended at least a 3-week period of immobilization in an above-elbow plaster cast.


The authors used preserved human radii to study the effect of osteotomy on the radius. Twenty bones were osteotomized, and 20 nonosteotomized bones served as controls. The osteotomy group included 10 bones with squared-corner osteotomies and 10 with beveled-corner osteotomy. The bones were then tested for breaking using a four-point bending apparatus. Osteotomized radii were significantly weakened with breaking strengths of only 24% of that in the control group. The beveled-osteotomy group appeared stronger than the squared-osteotomy group, although the difference was not significant. To reduce the incidence of fractures, the authors recommended excising no more than a third of the radial diameter of the bone, with postoperative immobilization of the forearm for 8 weeks.


This is an excellent and exhaustive review of the vascular basis of the radial forearm flap. The arterial and venous anatomy of the flap was studied in dissections of 56 cadavers. A variety of techniques, such as ink, latex, and barium sulfate injections, were used to determine the arterial inflow. The location and number of perforators in the overlying skin and vascular connections with the tendons and muscles and distal radius were well described. Venous drainage through the superficial and deep systems and the basis for the reversed venous flow in the distally elevated flap were discussed.

The authors reviewed complications from radial forearm flaps in 15 patients from two centers. In all patients the flap was transferred as a free flap. Complications included skin-graft failure, hand swelling and stiffness, reduced sensibility and strength, cold-induced symptoms, and fractures of the radius. In seven patients the flap included bone, and three of these patients had a radius fracture. Recommendations for minimizing complications at the donor site were discussed.


The authors described a totally new method of reconstructing the entire cervical trachea with a free forearm flap. An inverted tube was made from the forearm flap and placed between the subglottic trachea and an adjacent cutaneous fistula at the upper portion of the tracheal stoma. A permanent tracheal stoma was preserved, and an L-shaped silicone tube was inserted in the reconstructed cervical trachea and tracheostoma as a stent. The authors reported their experience with two patients who were able to speak following this procedure.
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Section 8E

UPPER EXTREMITY

Flexor Carpi Ulnaris Flap

CLINICAL APPLICATIONS

*Regional Use*
- Elbow

*Distant Use*
- Head and neck

*Specialized Use*
- Tendon transfer
- Elbow coverage
ANATOMY OF THE FLEXOR CARPI ULNARIS FLAP

A

Arterial supply to flexor carpi ulnaris

Branches of ulnar artery
Posterior ulnar recurrent artery
Flexor carpi ulnaris muscle
Ulnar artery
Brachial artery

B

Motor nerve to flexor carpi ulnaris

Ulnar nerve
Flexor carpi ulnaris muscle

Fig. 8E-1

Dominant pedicle: Posterior ulnar recurrent artery
Minor pedicle: Branches of ulnar artery
ANATOMY

Landmarks  The most superficial muscle on the ulnar side of the forearm.
Composition  Muscle.
Size  20 × 5 cm.
Origin  Two heads of origin: humeral and ulnar. The humeral head arises from the medial condyle of the humerus; the ulnar head arises from the posterior border of the ulna. The ulnar nerve and posterior ulnar recurrent artery run between the two heads of origin.
Insertion  Pisiform.
Function  Flexion and ulnar deviation of the wrist.

Arterial Anatomy (Type II)

Dominant Pedicle  Posterior ulnar recurrent artery
Regional Source  Ulnar artery.
Length  2 to 3 cm.
Diameter  1 to 2 mm.
Location  On the deep surface of the muscle, close to its origin.

Minor Pedicle  Distal ulnar perforating branches
Regional Source  Ulnar artery.
Length  2 to 3 cm.
Diameter  0.5 to 1 mm.
Location  Along the radial border of the muscle and the middle and distal third of the forearm.

Venous Anatomy

Venae comitantes accompany the arterial supply.

Nerve Supply

Motor  Ulnar nerve.
Vascular Anatomy of the Flexor Carpi Ulnaris Flap

Fig. 8E-2

Dominant pedicle: Posterior ulnar recurrent artery (D)
Minor pedicle: Branches of ulnar artery (m)
FLAP HARVEST

Design and Markings
The line drawn from the medial epicondyle of the humerus to the pisiform bone of the forearm outlines the location of the flexor carpi ulnaris (FCU) muscle. The dominant pedicle of the muscle, the posterior recurrent artery, enters the deep surface close to its origin from the medial epicondyle of the humerus. Incision is made along the line extending from the medial epicondyle to the pisiform bone.

Patient Positioning
The patient is placed in the supine position with the upper arm abducted on an arm board.

GUIDE TO FLAP DISSECTION
An incision is made along the middle third of the line drawn from the medial epicondyle to the pisiform bone. The FCU muscle is easily identified. It is the most superficial and most ulnar of the forearm muscles. Proximally, the muscle belly is in close contact with the muscle belly of the palmaris longus and the flexor carpi radialis. Deep to it lies the flexor digitorum profundus. The fleshy muscle fibers of the flexor carpi ulnaris extend only to within 7 or 8 cm of the wrist. This easily denotes the distal extent of flap dissection. Once identified, the flexor carpi ulnaris muscle fibers are dissected off the tendon and mobilized from distal to proximal. This allows for function preserving elevation of this muscle. Dissection proceeds from distal to proximal. Deep to and just radial to the tendon and muscle belly run the ulnar artery and nerve, which are protected during dissection. Dissection stops once sufficient muscle has been elevated for rotational coverage to the antecubital fossa or elbow region.
**FLAP VARIANTS**

- Tendon transfer flap
- Fasciocutaneous flap with flexor carpi ulnaris
- Fasciocutaneous flap with flexor carpi ulnaris and ulna

**Tendon Transfer Flap**

The flexor carpi ulnaris has been described for reconstruction of the triangular fibrocartilage complex in transfers for cerebral palsy, radial nerve palsy, and medial nerve palsy. These topics are beyond the scope of this atlas.

**Fasciocutaneous Flap With Flexor Carpi Ulnaris and With Flexor Carpi Ulnaris and Ulna**

As a variant of the ulnar forearm flap, the FCU can be harvested with the overlying skin paddle with or without a segment of ulna. The FCU is required in the bone flap variant to provide blood supply to the bony segment near the muscle origin. (See ulnar forearm flap variants in Section 8F.)

**ARC OF ROTATION**

The arc of rotation extends posteriorly to the elbow, and anteriorly to the antecubital fossa.

![Arc to elbow and antecubital fossa](Fig. 8E-5)

**FLAP TRANSFER**

Flap transfer is by direct transposition or through a short subcutaneous tunnel.

**FLAP INSET**

The flap is inset by direct suturing of the flap to its surrounding bed. The muscle is usually skin grafted when used for soft tissue coverage.

**DONOR SITE CLOSURE**

The skin opened for exposure can be closed primarily.
CLINICAL APPLICATION
This 40-year-old patient with rheumatoid arthritis had undergone total elbow arthroplasty 3 weeks earlier. The patient presented with a nonhealing surgical incision with serous drainage.

Fig. 8E-6  A, Surgical wound at presentation. B, The wound was surgically debrided. C, The flexor carpi ulnaris was harvested. D, The muscle was rotated 180 degrees to cover the olecranon and distal prosthesis. E, The healed wound is seen 6 months postoperatively. (Case courtesy Milan Stevanovic, MD.)
**Pearls and Pitfalls**

- The FCU muscle is the most powerful flexor of the wrist; therefore it should rarely be used for reconstruction.
- When this muscle is sacrificed, it is generally for preservation of function, or transfer to improve loss of function.
- Muscle harvest can be performed, keeping the tendon intact, which limits morbidity.
- Although the ulna can be taken in conjunction with the ulnar forearm flap, other bone donor sites do not require sacrifice of a functional muscle and offer better bone stock for reconstruction. Therefore this variant is rarely used.

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**EXPERT COMMENTARY**

**Milan Stevanovic**

**Indications**

The flexor carpi ulnaris is a bipennate muscle that can be used to cover small- to moderate-sized defects about the elbow. It can reach all surfaces (anterior, posterior, medial, and lateral) of the elbow. It has a strong, wide tendon that can be used for vascularized elbow ligament or triceps tendon reconstruction. The dual innervation of the humeral and ulnar heads of origin makes it possible to spare the humeral head of origin to retain flexor carpi ulnaris function while using the ulnar origin head for local soft tissue coverage of very small defects.

**Anatomic Considerations**

Both the dominant arterial pedicle and the innervation to the muscle are proximal. Preservation of the innervation to the muscle reduces the atrophy and fibrosis seen in denervated muscle transfers. In most patients there are two to seven vascular pedicles; the dominant pedicle typically lies within the first 5 cm from the medial epicondyle. There is a small possibility that the ulnar artery is absent. A Doppler study of the arm and forearm should be completed before planning to use this muscle.

![Image of Flexor carpi ulnaris](image.png)

**Fig. 8E-7** Vascular pedicles from the ulnar artery to the flexor carpi ulnaris.
Recommendations

**Technique**

The muscle should be dissected through a long incision along the medial side of the muscle, starting at the wrist flexion crease and extending proximally along the medial side of the muscle. The incision should extend to the medial epicondyle or to the soft tissue defect. The muscle belly extends nearly to the wrist flexion crease, which increases the surface area of defect that can be adequately covered with this flap. If tendon is needed for ligament or triceps tendon reconstruction, the distal portion of the muscle can be stripped away from the tendon. The dissection can be performed with loupe magnification from distal to proximal. The vascular pedicles are identified coming from the ulnar artery. More proximally, the dominant pedicle may arise from the ulnar artery or ulnar recurrent artery. After identifying the vascular pedicles, the muscle is elevated from lateral to medial off the ulnar periosteum. The more distal vascular pedicles can then be ligated, leaving the proximal two pedicles intact. If the most proximal pedicle has a smaller caliber, then both pedicles are left intact.

If a greater arc of rotation is needed for soft tissue coverage, the adequacy of the muscle perfusion can be assessed. With the tourniquet released, the more distal pedicle is temporarily clamped with a bulldog clamp. If the muscle retains adequate circulation, then the second pedicle can be safely divided.

To achieve a wider extent of soft tissue coverage, the muscle fascia can be longitudinally incised to allow the muscle to be spread out to cover a greater surface area. In addition, the long length of the muscle belly of the flexor carpi ulnaris allows the muscle to be fanfolded on itself.
If the tendon is needed for ligament or triceps tendon reconstruction, the reconstruction is completed first, and the muscle belly is then positioned to cover the soft tissue defect.

**Take-Away Messages**

A greater arc of rotation can be achieved by releasing the fascia and the proximal origin, as well as leaving only the proximal dominant pedicle. The flexor carpi ulnaris has a greater arc of rotation than the brachioradialis and can usually reach all surfaces of the elbow.

The surgeon must pay special attention to protecting the ulnar nerve. Compression or traction on the ulnar nerve must be avoided when insetting the muscle. After the muscle is rotated, the pedicles should be inspected to ensure that there is no tension or kinking of the pedicles.

**Bibliography With Key Annotations**


The flexor carpi ulnaris is an ever-present muscle of the anterior flexor compartment of the forearm. Variations of this muscle are uncommon, with additional slips or heads of muscles described, and only one reported case of an accessory muscle. The authors described a unique clinical case report in which an accessory flexor carpi ulnaris was identified and described the findings of 5000 cadaveric dissections of the forearm, performed as part of an ongoing institutional study of anatomic variations. An aberrant accessory forearm flexor muscle was identified incidentally at the wrist during surgery for an anterior interosseous to ulnar nerve transfer for management of ulnar nerve palsy. This muscle was seen running superficial to the ulnar nerve and radial to the FCU proper, arising from the common flexor origin and inserting at the triquetral carpal bone. This was therefore suitably acknowledged as an “accessory flexor carpi ulnaris.” The anomaly was identified as bilateral using ultrasound imaging, and was found to be anomalously innervated by the median nerve with nerve conduction studies.


The concept of muscle subunits has been introduced for limb reconstruction and functional conservation of donor site, yet it requires thorough understanding of neurovascular anatomy of muscles. The present study provides neurovascular details of forearm skeletal muscles. Twenty-eight forearms were totally dissected, 10 to observe extramuscular nerve distribution, 10 to observe intramuscular nerve distribution by a modified Sihler’s technique, and 8 to observe intramuscular artery distribution by aqueous barium sulfate infusion. The forearm muscles were classified into three different types according to Lym’s classification. Numbers of extramuscular and intramuscular nerves were counted and compared between the types. Intramuscular vascular distribution was also classified into three different types according to Mathes’s method. Intramuscular vascular distribution was compared with nerve distribution. There were some variations in the composition of muscular branches. Numbers of intramuscular nerve branches were significantly higher in muscle types IIa and III. Morphology and intramuscular neurovascular distribution of type II muscles are easy to split into two independent parts for functional muscular flap transfer according to morphology and intramuscular neurovascular distribution.


The authors reported their study to assess the detailed architectural properties of the human flexor carpi radialis and flexor carpi ulnaris muscles and their implications for tendon transfer surgery. Muscle fiber length was measured in six separate regions of the flexor carpi ulnaris and flexor carpi radialis from 10 cadaveric specimens. Sarcomere length was measured by laser diffraction for normalization. Moment
arms were estimated by measuring tendon excursion with respect to joint angle. The position of entry of the motor nerve branches into each muscle also was measured to establish limits for the safe length of muscle mobilization. Muscle fiber length varied significantly along both the FCU and FCR. Fiber length variability in the FCU was twice that of the FCR. Although the average fiber length for both muscles across all regions was similar, the proximal fibers of the FCU were longer compared with the proximal fibers of the FCR, and the distal fibers of the FCU were shorter compared with the distal fibers of the FCR. The 99% confidence interval for the second nerve branch entry into the muscles was located approximately 69 mm distal to the medial epicondyle for the FCU and approximately 73 mm distal for the FCR.


The authors reported their experience with 108 patients with isolated and persisting radial nerve palsy who underwent transfer of the flexor carpi ulnaris tendon alone to extensor digitorum communis, extensor indicis proprius, and extensor pollicis longus. Only patients with sufficient flexor carpi ulnaris muscle power (grade M5) underwent this procedure. Long-term functional results were reviewed at a mean postoperative follow up of 48 (range 3 to 120) months. In comparison with the contralateral hand, the range of extension of the wrist was less but extension of the fingers and the MCP joints were similar to that of the normal hand. All patients improved functionally and could cope with their routine activities. Most were able to return to their previous jobs. There was no obvious difference in the end result of using this single transfer from our previous results using the three tendon transfers which are commonly used to treat radial nerve palsy. The single flexor carpi ulnaris tendon transfer has some advantages in terms of simplicity, shorter operation time, less morbidity and less surgical scars.


Active and passive length-force curves of spastic flexor carpi ulnaris muscles were measured intraoperatively in 10 patients with cerebral palsy to study the variability in measured muscle function. Maximum active FCU force was in general situated near the neutral position of the wrist and varied between 40 and 135 N. Passive forces varied between 1 and 8 N at maximum active force. The potential active excursion varied between 4 and 7 cm, while patients moved their wrists from flexion to extension along different parts of the active length-force curve. The authors measured a large inter-individual variety of spastic flexor carpi ulnaris muscle function in this group of patients. Thus tailoring the surgical technique of tendon transfer to the specific needs of the desired function requires the assessment of muscle-specific data for each individual patient.


The authors reported on a muscle with features suggesting an anomalous conjoined palmaris longus and flexor carpi ulnaris. To their knowledge this had not been described previously. In light of improved imaging techniques, the authors questioned the previously published view that surgery is indicated for swellings suspected as forearm muscle anomalies that are clinically benign and otherwise asymptomatic.


A functioning free muscle transfer is a well-established modality of restoring upper limb function in patients with significant functional deficits. Splitting the neuromuscular compartments of the free muscle based on its intramuscular neural anatomy and using each compartment for a different function would allow for restoration of two functions instead of one at the new distant site. The authors previously reported on the clinical use of a pedicled split flexor carpi ulnaris muscle transfer. In this report they described the use of this muscle as a functioning free split muscle transfer to restore independent thumb and finger extension in a patient with total extensor compartment muscle loss in the forearm and a concomitant high radial nerve avulsion injury. Nine months postoperatively, the patient was able to extend his thumb and fingers independent of each other.

The flexor carpi ulnaris is a useful local muscle flap in the forearm and elbow. However, it is an important palmar flexor and ulnar deviator of the wrist, and functional loss may arise from the use of this muscle in its entirety. The flexor carpi ulnaris is made up of two distinct neuromuscular compartments. This arrangement allows splitting of the muscle and the potential use of the larger ulnar compartment as a local muscle flap while maintaining the humeral compartment as an ulnar deviator and palmar flexor of the wrist. The authors reported two cases illustrating the clinical use of the split flexor carpi ulnaris as a local muscle flap.


The branching pattern of the ulnar nerve in the forearm is of great importance in anterior transposition of the ulnar nerve for decompression after neuropathy of cubital tunnel syndrome and malformations resulting from distal end fractures of the humerus. In this study, 37 formalin-fixed forearms were used to demonstrate the muscular branching patterns from the main ulnar nerve to the flexor carpi ulnaris muscle and ulnar part of the flexor digitorum profundus muscle. Eight branching patterns were found and classified into four groups according to the number of the muscular branches leaving the main ulnar nerve.


The authors evaluated the vascular perfusion of a flexor carpi ulnaris turnover flap, based on the most proximal primary vascular pedicle that would permit a proximal turnover flap reconstruction to include the olecranon tip. In 12 fresh-frozen, proximal humeral human amputation specimens, the flexor carpi ulnaris flap was elevated from distal to proximal, preserving the most proximal primary vascular pedicle to the muscle belly that would permit flap coverage of the olecranon tip. The axillary artery was injected with india ink after ligation of radial and ulnar arteries at the wrist. After injection, each specimen was sectioned transversely at 0.5 cm increments to assess vascular perfusion of the muscle using loupe magnification. The authors concluded that use of a proximally based, pedicled flexor carpi ulnaris muscle turnover flap provides a reliable option for soft tissue reconstruction at the posterior elbow. The authors observed consistent arterial perfusion of the muscle flap when preserving a proximal vascular pedicle 5.9 cm distal to the olecranon tip.


The author described the successful use of a proximally based flexor carpi ulnaris myocutaneous flap to reconstruct a distal tricipital myocutaneous defect for four patients. The flap is recommended for patients who have undergone multiple operations, for active reconstruction of the distal third of the triceps muscle in association with medium-sized cutaneous defects on the posterior aspect of the elbow.


Total or subtotal glossectomy following resection of intraoral tumors causes significant morbidity. Recent surgical endeavors have focused on the creation of a neotongue with both sensory and motor innervation. Although various local or regional free flaps have been used for this purpose, the optimal donor site remains undecided. The authors compared the neurovascular anatomy of the brachioradialis and flexor carpi ulnaris to assess their suitability as donor muscles together with overlying skin for functional total or subtotal tongue reconstruction. Eighty-eight brachioradialis and 80 flexor carpi ulnaris muscles were studied, composing 120 dissected specimens, 18 arterial studies, two venous studies, 20 histologic studies, and eight neurovascular studies. The authors delineated the anatomic advantages of the flexor carpi ulnaris over the brachioradialis for total or subtotal tongue reconstruction.

The authors reported a new substitution technique as a choice for repairing both acute and chronic injuries of the ulnar collateral ligament of the elbow. Different researchers have described different techniques to reconstruct the medial ligament complex with similar results (with the use of grafts). There is a shared variable in the latest reports, the interpretation of the anterior bundle as the most important structure, for medial elbow stability and the only structure to be repaired as well. The approach to the medial structures of the elbow is similar to most of the surgical techniques. It consists of an incision on the medial aspect of the elbow, centered on the epicondylye, 4 inches long. The reconstruction uses a strip of the aponeurosis of the flexor carpi ulnaris reinforced with Krakow stitches. The graft is harvested using the strong aponeurosis of the flexor carpi ulnaris, a vascularized structure, a viable option and with sufficient resistance to bear the tension of the inner aspect of the elbow. The surgical morbidity is also reduced as the graft is not taken from other zones. As the distal insertion of the neoligament, the proximal fixation of the flexor carpi ulnaris is used in the sublime tubercle, inverting the direction of the fibers of this strip from distal to proximal. The proximal fixation of this ligament is an osseous tunnel in the epitroclea secured with an interference screw. Common complications are those resulting from the approach and the ulnar nerve manipulation. Because of the satisfactory stability outcome achieved by this technique, early rehabilitation may start without inconvenience.


Seventeen fresh-frozen cadaveric upper extremities were used to evaluate the coverage patterns of whole and split flexor carpi ulnaris pedicle muscle flaps for posterior elbow soft tissue defects. The whole FCU was raised to the dominant vascular pedicle and transposed proximally over the olecranon. The widths of coverage at 2 cm distances about the posterior elbow were measured. Widths were also measured after making three longitudinal cuts in the fascia and after suturing the muscle to adjacent soft tissue under tension. The FCU was also split into its ulnar and humeral heads along the central tendon. The larger ulnar head was transposed and the widths again measured. Midforearm circumference, elbow circumference, and ulnar length were assessed for ability to predict flap width. The whole muscle under no tension provided an average of 2.7 cm width coverage at the tip of the olecranon process. Cutting the fascia provided approximately 15% additional width and suturing the muscle to the surrounding soft tissue an additional 25%, to approximately 4 cm. The isolated flexor carpi ulnaris ulnar head provided approximately 75% of the width of the entire muscle. Midforearm circumference was the most predictive of flap width, and divisors were generated that improved the accuracy of predicting the width for outlier specimens. The dominant pedicle was a consistent distance relative to the end of the central tendon and the olecranon tip.
ANATOMIC LANDMARKS

**Landmarks**
A line from the medial epicondyle of the humerus to the lateral edge of the pisiform bone marks the mid and distal forearm course of the ulnar artery, which should bisect any skin design. The flap occupies the medial aspect of the forearm along the middle and lower thirds. Its distal limit is at the wrist crease.

**Size**
Skin: 8 × 12 cm; muscle: 5 × 20 cm; bone: up to 12 cm.

**Composition**
Fasciocutaneous, myocutaneous, osteomyocutaneous.

**Dominant Pedicle**
Ulnar artery.

**Nerve Supply**
Medial antebrachial cutaneous nerve (C8 to T1).
Section 8F

UPPER EXTREMITY

Ulnar Forearm Flap

CLINICAL APPLICATIONS

Regional Use
Upper extremity

Distant Use
Head and neck reconstruction
Upper extremity
Lower extremity

Specialized Use
Penile reconstruction
A common interosseous artery arises within 2 cm of the brachial bifurcation. Flap placement and dissection are located distal to this artery, which remains intact. The basilic vein receives tributaries from the dorsal venous arch on the ulnar aspect of the back of the hand. It ascends on the ulnar aspect of the forearm accompanied in the distal third by the ulnar branch of the medial antebrachial cutaneous nerve. Sensory innervation of the ulnar forearm flap is based on the medial antebrachial cutaneous nerve branches, which are associated with the basilic vein proximally.

Dominant pedicle: Ulnar artery
ANATOMY

Landmarks
The flap occupies the medial aspect of the forearm along a line drawn from the medial epicondyle of the humerus to the lateral edge of the pisiform bone.

Composition
Fasciocutaneous, myocutaneous, osteomyocutaneous. The flap compares well with the radial forearm flap for both application and tissue quality.

Size
Skin: 8 × 12 cm; muscle: 5 × 20 cm; bone: up to 12 cm.

Arterial Anatomy

Dominant Pedicle  Ulnar artery

Regional Source  Brachial artery.

Length  4 cm.

Diameter  3 mm proximally; 2.5 mm distally.

Location  The ulnar artery is the larger of the two terminal branches of the brachial artery. The most proximal septocutaneous perforator of the ulnar artery arises 4 cm distal to its common interosseous branch. Proximally on the forearm, the ulnar artery joins the ulnar nerve on its lateral surface deep to the flexor carpi ulnaris (FCU) muscle. The ulnar artery is closely associated with the ulnar nerve in the distal two thirds of the forearm; it is found on the lateral side of the ulnar nerve. At the wrist, the ulnar artery passes superficial to the flexor retinaculum and enters the hand between the pisiform bone and the hook of the hamate bone. The ulnar artery continues distally to form the superficial palmar arch. It also sends a smaller branch to form the deep palmar arch with the terminal portion of the radial artery.

Venous Anatomy

The ulnar forearm flap has both a superficial and a deep venous system. The basilic vein runs in the ulnar aspect of the forearm and is accompanied in the distal third by the ulnar branch of the medial antecubital cutaneous nerve, which is often deep to the vein. At the antecubital fossa, the basilic vein is joined by the median cubital vein and ascends in the bicipital groove, where it is closely associated with the ulnar branch of the medial antecubital cutaneous nerve, which is located medial to the vein, and the anterior branch of the medial antecutaneous nerve, located lateral to the vein. The deep venous system comprises paired venae comitantes that travel with the ulnar artery. The basilic vein is often chosen as the main vein that drains the flap.

Nerve Supply

Sensory  The medial antecubital cutaneous nerve (C8 to T1) arises from the medial cord of the brachial plexus, accompanies the brachial artery, and exits the fascia of the arm, with the basilic vein dividing into anterior and ulnar branches. The anterior branch supplies the anteromedial surface of the forearm. The ulnar branch, which passes anterior to the medial epicondyle, supplies the skin on the posteromedial surface of the forearm to the wrist.
**Vascular Anatomy of the Ulnar Forearm Flap**

**A**, Dissection of the ulnar artery flap skin paddle is started from radial to ulnar and is performed in a suprafascial plane to minimize donor site morbidity. **B**, The dissected ulnar artery is seen coursing within the intermuscular septum between the flexor digitorum superficialis and flexor carpi ulnaris muscles. Note cutaneous perforators to the volar ulnar forearm skin and multiple muscle perforators to the flexor carpi ulnaris and flexor digitorum superficialis muscle bellies. The retracted flexor digitorum superficialis muscle belly shows multiple muscle, myocutaneous, and cutaneous perforators originating from the ulnar artery. The ulnar artery runs within the intermuscular septum between the flexor carpi ulnaris and the flexor digitorum superficialis and is intimately bound to the ulnar nerve. The ulnar artery perforators are predominantly myocutaneous in the proximal forearm, and mostly septocutaneous in the distal forearm. **C**, The ulnar artery flap is harvested based on five cutaneous perforators. As the ulnar artery runs deeper within the intermuscular septum between the flexor digitorum superficialis and flexor carpi ulnaris muscle bellies, the cutaneous perforators become longer from distal to proximal. Note the suprafascial harvest of the ulnar artery flap to minimize donor site morbidity. (Dissection courtesy Michel Saint-Cyr, MD.)
FLAP HARVEST

Design and Markings
The flap is designed on the proximal or central forearm; a distally placed flap would have less vascularity, because there is a paucity of septocutaneous perforating vessels in the distal forearm. A line drawn from the medial epicondyle of the humerus to the lateral edge of the pisiform bone mirrors the course of the ulnar artery; this can be confirmed by Doppler ultrasound. A third of the flap should be located radial to the ulnar vessel. A tourniquet can aid in marking the basilic vein, which is included in the flap.

Fig. 8F-3 The location of the ulnar artery distally is marked by the line connecting the medial epicondyle of the humerus and the pisiform bone. This is confirmed by Doppler ultrasonography. The flap design should have at least one third of the skin paddle radial to this line and should include the basilic vein.

Patient Positioning
The patient is placed in the supine position with an armboard and a tourniquet on the arm.
GUIDE TO FLAP DISSECTION

An incision is made on the radial margin, including the deep fascia of the forearm. The distal margin is incised and the ulnar artery is identified. At this point, the ulnar artery can be temporarily occluded with a clamp and the tourniquet deflated to confirm perfusion if the Allen’s test has not been performed. The ulnar artery is transected and the proximal margin is incised, again with careful identification of the ulnar artery and measures to avoid injury to the basilic vein. If a sensate flap is desired, the anterior and ulnar branches of the medial antebrachial cutaneous nerves are identified and spared.

Dissection continues from radial to ulnar beneath the deep fascia toward the intermuscular septum, which separates the flexor digitorum sublimis and the flexor carpi ulnaris muscles. All septocutaneous vessels that run in the intermuscular septum to the deep fascia are preserved.

**Fig. 8F-4  A,** The flap is raised radial to ulnar, with early identification of the ulnar artery and nerve distally and the basilic vein and medial antebrachial cutaneous nerves proximally.

**Fig. 8F-4  B,** The flap is further dissected to the intermuscular septum containing the perforators to the skin. The ulnar artery is divided distally, and any branches to surrounding muscles are also divided.
Dissection continues on the ulnar surface of the septum. Muscular branches to the flexor carpi ulnaris and flexor digitorum profundus are divided.

Dissection proceeds from distal to proximal, separating the ulnar artery from any soft tissue attachments until the flap is attached proximally only by the ulnar artery pedicle, the basilic vein, and the accompanying nerves.

**FLAP VARIANTS**

- Fasciocutaneous flap with flexor carpi ulnaris
- Fasciocutaneous flap with flexor carpi ulnaris and ulna
- Flow-through flap
Fasciocutaneous Flap With Flexor Carpi Ulnaris
The flexor carpi ulnaris muscle can be included in the fasciocutaneous flap. Dissection is similar to that described for the standard flap. The FCU is a class II muscle with a larger dominant pedicle and smaller minor pedicles. It is noteworthy that when the FCU is dissected with the ulnar forearm flap, it includes only the minor pedicles. The nerve supply to the muscle is a branch of the ulnar nerve, which is found proximally near the elbow. After the fasciocutaneous portion of the flap is isolated, the flexor carpi ulnaris muscle is detached proximally from its two heads of origin, the medial condyle of the humerus and the posterior border of the ulna. This distal tendinous insertion is cut proximal to its insertion into the pisiform bone. After the muscle is elevated, the motor nerve is identified and further dissected if the muscle will be used as a functional transfer.

Fig. 8F-5 The flexor carpi ulnaris muscle is included with the cutaneous paddle.

Fasciocutaneous Flap With Flexor Carpi Ulnaris and Ulna
An osseous segment of the ulna, up to 12 cm, can be included with flap. It is important to include the proximal portion of the flexor carpi ulnaris muscle with its myoperiosteal branch, which supplies this osseous segment. The width of the bony segment should be 0.75 cm thick.

Fig. 8F-6 An osseous segment of ulna may be included in the flap. A portion of the flexor carpi ulnaris muscle is included with this myoperiosteal branch, which supplies the osseous segment.
Flow-Through Flap
The caliber of the ulnar vessels proximally and distally makes the ulnar forearm ideal for use as a flow-through flap. This is most commonly used in the extremities to revascularize a dysvascular segment or to incorporate multiple free flaps in reconstruction, as is often performed in the head and neck.

**ARC OF ROTATION**

**Standard Flap**
The arc of rotation of the standard flap easily reaches the antecubital fossa, the elbow, and the forearm.

![Diagram showing the arc of rotation](image)

**FLAP TRANSFER**

**Standard Flap**
The flap is transposed into the recipient site either by direct communication or through a subcutaneous tunnel. There must be no compression of the pedicle or kinking on its transposition.

**Free Flap**
Standard microsurgical principles are employed to avoid tension on the flap or on the pedicle.

**FLAP INSET**

**Pedicled Flap**
The flap must be inset without tension, with adequate space provided for the pedicle. It is essential to allow for postoperative swelling.

**Free Flap**
The flap should be inset without tension; the vascular pedicle is positioned carefully to avoid tension or kinking. In bone harvest, the bone inset is performed before microsurgical reanastomosis to prevent injury to the pedicle from unnecessary tension. In a muscle harvest in which a functional muscle is required, the resting muscle length must be reestablished for best function.
DONOR SITE CLOSURE

All Flap Variants

Direct donor site closure can be accomplished in most cases. When primary closure is not possible, a skin graft can be used. The donor site must not be closed under too much tension to avoid a tourniquet-like effect, which can compromise the blood supply to the hand, especially when postoperative swelling is taken into account.

CLINICAL APPLICATIONS

This 60-year-old man had a 3 by 3 cm nonhealing elbow wound and forearm hardware. An ulnar artery flap reconstruction was planned.

Fig. 8F-8  A, The wound defect is seen with exposed bone. B, Ulnar artery flap design. C, The ulnar artery flap was elevated and the donor site skin grafted. D, The flap has been inset and wound closed. (Case courtesy Ernest Chiu, MD.)
This 56-year-old man had a lateral tongue squamous cell carcinoma.

Fig. 8F-9  A, The patient’s tongue cancer is seen preoperatively. B, The ulnar artery skin flap inset is seen postoperatively. C and D, Donor site. (Case courtesy Ernest S. Chiu, MD.)

**Pearls and Pitfalls**

- The ulnar forearm flap supplies tissue similar to that of the radial forearm flap; an advantage of the ulnar flap is a more aesthetically favorable, well-hidden donor site that is relatively hairless and can include a functional muscle, the flexor carpi ulnaris.
- Postoperative pain and immobilization are minimal with the forearm ulnar flap.
- The flap allows elevation and recipient site dissection to be carried out by two teams.
- Sacrifice of the ulnar artery is less likely to result in ischemic consequences to the hand than sacrifice of the radial artery. However, this flap does require sacrifice of a major artery supplying the forearm.
- The ulnar forearm flap is more proximally based than the radial forearm flap and therefore has a shorter vascular pedicle.
- When bone is harvested with the flap, the patient should be placed in a cast for a minimum of 3 weeks to prevent fracture of the ulna.
- Transient postoperative paresthesias can occur postoperatively in the ulnar two digits.
EXPERT COMMENTARY
Ernest S. Chiu

Indications
The ulnar artery forearm flap can be used in all situations in which the radial artery forearm flap is being considered for reconstruction.

Advantages and Limitations
The thin fasciocutaneous flap is reliable and easy to harvest. It can be used as a pedicled or free tissue transfer flap with an excellent robust blood supply to the skin paddle. The donor site can be well concealed on the ulnar aspect of the forearm and tends to have less hair on its skin surface. Also, the donor site does not have the raised, tendinous flexor carpus radialis, which can be difficult to heal, even when inadequately skin grafted. Its limitations are that an important blood supply to the hand is sacrificed; therefore the flap is contraindicated if the result of the Allen’s test is abnormal. The color match is suboptimal for reconstructing visible anatomic head or neck defects. Although a small segment of ulnar bone can be harvested with the flap, this is not recommended—thin ulnar bone is prone to fracture. The flap harvest must be performed with utmost attention, because the ulnar nerve is vulnerable to injury, since it runs directly on the ulnar side of the ulnar artery. The donor site frequently requires skin grafting, which may be disfiguring.

Personal Experience and Insights
The ulnar artery is located between the ulnar nerve and the flexor digitorum tendons. When the anterolateral thigh flap is found to be too bulky, the ulnar artery flap is my preferred thin, fasciocutaneous flap for both upper extremity regional flap reconstruction as well as lower extremity and head and neck free flap reconstruction.

Recommendations
Planning
During the initial consultation, an Allen’s test is performed in the patient’s nondominant arm. If the result is normal, blood is not drawn from that donor site arm, nor are intravenous lines placed in the arm. Before induction of anesthesia, an Allen’s test is confirmed by placing an oxygen saturation pulse oximeter on the patient’s middle finger and manually occluding both the radial and ulnar arteries. After releasing the radial artery occlusion, the oxygen saturation curve should return to baseline within 3 to 5 seconds. If the flap is to be used for free tissue transfer, a temporary upper extremity tourniquet is placed to promote forearm basilic vein engorgement. These veins can be marked and used as an alternative venous drainage choice if the venae comitantes size match to the recipient vessels is unfavorable.

After the defect size has been determined, the skin paddle is designed one and a half to two times larger than the defect, centered over the ulnar artery.

Technique
The skin paddle design will allow the redundant proximal forearm flap skin to be used as a full-thickness skin graft to the donor site. A more favorable texture, contour, and color match will result. The upper extremity is prepared in sterile fashion to the axilla, and a sterile tourniquet is applied to the upper arm. When possible, the surgeon sits during the flap harvest.
After the arm is exsanguinated, the tourniquet is placed at 100 mm Hg above systolic pressure.

The flap is harvested by completing ulnar, radial, and proximal wrist crease skin incisions. The ulnar artery is identified and ligated, and the flap is harvested in a distal-to-proximal fashion. There are small perforating branches that run between the ulnar pedicle to the overlying skin; these should be preserved. Dissolvable sutures are used to tack the skin paddle to the underlying pedicle to prevent flap avulsion. Because the ulnar artery is in close proximity to the ulnar nerve, nerve identification is important, and the nerve should not be skeletonized. Unlike a radial forearm flap, the muscle bellies of the flexor digitorum tendons are wide and flat, allowing a more uniform and favorable surface for grafting. When available, a basilic vein entering the proximal aspect of the flap should be maintained as an alternative vein choice. Dissection of the ulnar artery pedicle is continued proximally until adequate pedicle length is obtained. The tourniquet is released to check for skin flap perfusion. A marking pen is used to identify pedicle orientation to minimize the risk of pedicle twisting or kinking. When the recipient vessels are ready, the flap harvest can be performed.

The forearm skin around the flap harvest location should be undermined and sutured to underlying fascia and muscle to decrease the size of the donor site defect. Dissolvable sutures are selectively placed in the donor site area to promote a flat favorable recipient skin graft location. Extra skin harvested from the flap skin paddle can be separated from the skin paddle, thinned, and sutured to cover the donor site. Meshing of the skin graft creates an unattractive gridlike pattern at the donor site. Pie-crusting of the skin graft and irrigation with saline solution under the graft to flush out blood and fluid will decrease the risk of incomplete skin graft take. An Adaptec or Xeroform dressing is applied over the skin graft site, and a 125 mm Hg VAC negative pressure dressing is applied. An ulnar gutter splint is used to minimize skin graft shearing. Skin graft take is checked 3 to 5 days later.

**Take-Away Message**

This is a practical, reliable, thin fasciocutaneous flap with a robust blood supply that can be used in many reconstructive cases.

**Bibliography With Key Annotations**


The authors described a modification of the free ulnar artery forearm flap that has the benefit of the anastomosis of large-caliber vessels and the reassurance of a reconstructed ulnar artery for perfusion of the donor hand.


The surgical anatomy of the dorsal branch of the ulnar nerve and artery on the dorsal aspect of the hand is important in the design of neurocutaneous flaps for reconstructive surgery and serves as a donor site for nerve grafts. The authors studied the course, location, and diameter of the dorsal branches of the ulnar nerve and artery from anatomic and reconstructive perspectives. The upper limbs of 14 (7 left and 7 right) and 22 formalin-preserved adult cadavers (15 left and 7 right) were dissected in two
The distances to specific anatomic landmarks were also measured from the proximal forearm toward the middle phalanges of the fourth and fifth fingers. These data may help the surgeon to design neurocutaneous flaps nourished from the dorsal branches of the ulnar nerve and artery, aid in harvesting nerve grafts from the dorsal branch of the ulnar nerve, and provide a safe surgical approach to the dorsum of the hand.


The ulnar forearm flap is not frequently used for oromandibular reconstruction. This retrospective study of 32 patients evaluated the usefulness of the ulnar free flap for reconstruction. The ulnar forearm flap was combined with an osseous flap in 24 patients. Nine women and 23 men with a mean age of 58.15 years composed the study population. Squamous cell carcinoma was the diagnosis in 93.75% of cases (56.25% T4), of which 20% were recurrent cases. Functional evaluation of swallowing was based on the University of Washington Questionnaire (UWQ). The mean hospital stay was 9.8 days. The external carotid (100%) was the recipient artery, and the internal jugular (74.07%) was the main recipient vein. Overall flap survival was 96.8%. One flap was lost to unsalvageable venous thrombosis. Major local complications were seen in 9.4% of cases and included partial flap loss, hematoma, and an orocutaneous fistula. Twenty-one patients were available for functional evaluation. Speech was rated excellent and good in 33.3% of patients. Swallowing was found good in 28.6% of patients. Cosmetic acceptance was rated good in 71.4% of cases. The ulnar forearm is a useful free flap in oromandibular reconstruction. It is available when the radial artery is the dominant artery of the hand. Because it is more hidden, it may be more cosmetically accepted. It affords pliable soft tissue for lining and/or covering of oromandibular defects, and can be used as a second choice after other free flaps have failed.


The authors presented their experiences with the ulnar flap based on the distal cutaneous branch of the ulnar artery. Twenty-four patients underwent surgery for soft tissue defects of the hand between January 2003 and December 2008. Fifteen cases had a soft tissue defect on the palmar aspect of the hand, and nine cases had defects on the dorsal aspect. The size of the flaps ranged from 5 to 12 cm long and 4 to 8 cm wide. Two flaps developed partial necrosis (25% to 35% of their area). In the other cases, both the donor and recipient sites healed successfully. No patient complained of cold intolerance of the hand or any altered sensation in the forearm. The range of motion of the wrist and hand joints was within normal limits in most cases: 14 cases with excellent, 8 cases with good, 2 cases with fair, and 0 case with poor results according to the total active motion (TAM) criteria. None of the patients had limitations in activities of daily living. Because the flap does not compromise the dominant hand arteries and provides a reliable blood supply, it is a good choice for soft tissue reconstruction of defects in the dorsal and palmar aspects of the hand.


The authors conducted this prospective study to assess the blood flow of the radial and ulnar arteries before and after radial forearm flap raising. Twenty-two patients underwent radial forearm microvascular reconstruction for leg soft tissue defects. Blood flow of the radial, ulnar, and recipient arteries was measured intraoperatively by transit time and ultrasonic flowmeter. In the in situ radial artery, the mean blood flow was 60.5 ± 47.7 ml/min before, 6.7 ± 4.1 ml/min after raising the flap, and 5.8 ± 2.0 ml/min after end-to-end anastomosis to the recipient artery. In the ulnar artery, the mean blood flow was 60.5 ± 43.3 ml/min before harvesting the radial forearm flap and significantly increased to 85.7 ± 57.9 ml/min after radial artery sacrifice. A significant difference was also found between
this value and the value of blood flow in the ulnar and radial arteries pooled together. The vascular resistance in the ulnar artery decreased significantly after the radial artery flap raising (from 2.7 ± 3.1 to 1.9 ± 2.2 peripheral resistance units). The forearm has a conspicuous arterial vascularization, not only through the radial and ulnar arteries, but also through the interosseous system. Raising the radial forearm flap increases blood flow and decreases vascular resistance in the ulnar artery.


The transverse ulnar forearm flap (TUFF) was used to reconstruct different recipient sites in five consecutive cases based on the specific requirement for a small thin, hairless flap with a long pedicle. Recent studies have clarified the benefits of the ulnar forearm flap: a less inconspicuous donor site and a primary donor site closure with a radially based fasciocutaneous flap. The TUFF is designed with its long axis transverse and distal margin parallel with a wrist flexion crease. An incision is extended proximally along the ulnar artery pedicle as far as the takeoff from the brachial artery, if needed. After elevating the ulnar forearm flap in the standard fashion, transverse primary closure of the donor site is obtained by elevating a large volar forearm fasciocutaneous flap based on the radial artery and advanced distally with a V-Y advancement. Any dog-ear is tailored, and the wrist is flexed at 30 degrees. In the authors’ series, all TUFF and radial fasciocutaneous flaps survived completely without partial or total losses or ischemic hand complications. One patient had a wide scar at the proximal forearm Y junction that was revised. Two-point fingertip discrimination and range of motion were satisfactory. They noted that the TUFF is a synthesis of variations of previously described forearm flap techniques and provides a specialized flap in situations where small, thin, pliable, hairless fasciocutaneous flap with a long vascular pedicle are necessary. These characteristics make it appropriate in orbital reconstruction and palatal surgery.


The proximal ulnar artery has several branches, including perforators that are directly derived from the ulnar artery and anterior/posterior recurrent arteries. There are only a few reports of flaps that use the anterior/posterior recurrent arteries, and flaps employing their perforators as a main pedicle are yet to be reported. In this study, 22 posterior ulnar recurrent artery perforator (PURAP) flaps were employed for elbow and forearm reconstruction; all flaps were vascular pedicled island flaps. The flaps were analyzed in terms of the cause of injury, recipient site, vascular pedicle of the flap, flap size and survival, and quality of the outcome. Donor site morbidity, including the development of scars and numbness, was also evaluated. The perforator used was the medial and posterior perforator in 14 (63.6%) and 8 (36.4%) cases, respectively. The average flap size was 10 by 5 cm. Six months after the operation, the outcomes were judged to be excellent in 15 cases (68.2%), good in 6 cases (27.3%), and poor in 1 case (4.5%) because of partial necrosis of the distal part of the flap. The authors stated that PURAP flaps can be harvested with two types of perforator pedicles (the medial or posterior perforator) and offer greater safety and flexibility, and less donor site morbidity than existing flaps used for elbow and forearm reconstruction. The ability to close the donor site primarily is a significant benefit of this flap.


A radial artery free flap was dissected from a traumatically amputated forearm. During dissection the arterial tree was found to be abnormal, with no radial artery. The arterial supply was based on co-dominant median and ulnar arteries. This description raises issues regarding anatomic vascular aberrations when planning forearm flaps.


To consider the pros and cons of the microvascular ulnar forearm flap compared with its radial counterpart, this study compares the use of these two flaps for head and neck reconstruction. In 75 patients, 51 ulnar and 24 radial forearm flaps were used. Both groups were compared regarding flap dissection, suitability of the flap for the recipient region, complication rate, and secondary morbidity in the donor region. Furthermore, in 40 healthy volunteers, the thickness of the subcutaneous tissue layer was measured by ultrasonography. The flap survival rate and wound healing in the recipient region showed no differences. Clinical and experimental results demonstrated a thinner subcutaneous layer in the ulnar aspect of the forearm. Compared with its radial equivalent, closure of the ulnar donor side by skin grafting resulted in a significantly lower complication rate.


The authors conducted a study to evaluate the outcome of reconstruction with the ulnar forearm free flap (UFFF). The UFFF was used to reconstruct soft tissue defects in the head and neck area in 15 patients. The outcome was registered from the patient notes, clinical examination, and from interviews with patients. All 15 UFFFs appeared successful. Thirteen donor sites healed without complications. Two donor sites showed minor wound-healing problems. No patient had abnormal sensation in the distribution area of the ulnar nerve. All patients were satisfied with the appearance of the scar and shape of the donor site. The authors stated that the UFFF should be considered as a reconstruction method for soft tissue defects in the head and neck area instead of the radial forearm free flap, as the donor site of the UFFF is barely noticeable, which makes patient acceptance more likely.


The author described a new flap that resulted from a study of the vascular distribution of the ulnar dorsal artery, with a focus on the distal and proximal branches with their anastomoses. Green latex was injected into the brachial artery of the proximal limbs of 25 cadavers. After 48 hours, the vessels were dissected beginning at the ulnar dorsal artery and following its descending and ascending branches. In two of the specimens, an injection of methylene blue was administered in the ulnar artery to look for reverse flow from the descending branch. The ulnar dorsal artery was located in all injected limbs with a constant distribution. It had two branches: a descending one that distributed under the abductor digiti quinti muscle and anastomosed with a deep branch of the ulnar artery, and an ascending one supplying the proximal third of the forearm. Retrograde flow in the descending branch was found by injecting dye. Based on these findings, a flap with reverse flow that the author called a “retrograde ulnar dorsal flap” was designed at the expense of the descending branch by ligating the ulnar dorsal artery where it originates. This makes it possible to cover soft tissue defects that are more distal on the hand.


The radial forearm fasciocutaneous free flap has become the reconstructive tissue of choice for the majority of soft tissue defects in the head and neck. The forearm skin has many of the ideal soft tissue characteristics that optimize reconstruction and rehabilitation in these patients. The tissue is malleable, supple, and moldable in three dimensions; has a reliable pedicle; and can be harvested with a two-team approach. In some patients, the radial forearm cannot be used. An alternative is to use the adjacent tissue, which shares identical tissue characteristics. This tissue gets its vascular supply from the ulnar artery. The purpose of the report was to describe the authors’ experience with the ulnar fasciocutaneous free flap in head and neck reconstruction. The authors presented a retrospective review of all patients undergoing ulnar fasciocutaneous free tissue transfer by a group of microvascular surgeons was performed. Thirty patients underwent free tissue transfer using the ulnar fasciocutaneous free flap. The male-to-female ratio was 3:1. Defects were located in the oral cavity, oropharynx, neck skin, and soft tissue of
the lateral skull. The average size of the skin paddle that was transferred was 7 by 10 cm (range 3 by 5 to 9 by 12 cm). The mean area of tissue that was transferred was 70 cm² (range 15 to 108 cm²). Vessel sizes were somewhat smaller than the comparable radial forearm. One patient had complete loss of the skin graft on the donor site. There were no median nerve or other wound-healing problems. Two flaps were lost in the postoperative period. Indications for use of the ulnar fasciocutaneous free flap were a failed Allen’s test (23), use of a less hairy part of the forearm (3), and surgical preference (4).

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Chapter 9

Hand

The hand is a unique fusion of form and function. Deficits in the hand run the gamut from congenital deformity to traumatic injuries. When reconstructing defects within the hand, the surgeon must remember that maintenance or improvement of hand function should always take precedence over form or aesthetics. These reconstructive flaps limit morbidity and address quality of life by affording rapid return to work and to normal activities. Many of these procedures will allow the replacement of like with like tissues, the toe-to-hand transfer representing the pinnacle of this concept. One should remember always that a fully functional hand is a cosmetic hand.

Abductor Digiti Minimi Flap
Great Toe (Hallux) Flap
Homodigital Neurovascular (Littler) Island Flap
Second Toe Flap
Dorsal Metacarpal Artery Flap
Cross-Finger Flap
Kleinert-Atasoy V-Y Flap
Moberg Advancement Flap
ANATOMIC LANDMARKS

Landmarks
The muscle forms the bulk of the volar border of the palm, extending from the distal wrist crease to the distal palmar crease.

Size
5 × 1 to 2 cm.

Origin
Pisiform bone of the distal carpal row.

Insertion
Ulnar-volar base of the proximal phalanx of the small finger and dorsal aponeurosis of the extensor digiti minimi.

Function
Small finger abduction.

Composition
Muscle.

Flap Type
Type I.

Dominant Pedicle
Deep palmar artery.

Nerve Supply
Motor: Deep branch of the ulnar nerve.
Section 9A

HAND
Abductor Digiti Minimi Flap

CLINICAL APPLICATIONS

Regional Use
Wrist

Specialized Use
Functional (Huber) transfer
ANATOMY OF THE ABDUCTOR DIGITI MINIMI FLAP

Fig. 9A-1

**Dominant pedicle:** Deep palmar artery

- **A**
  - Muscle showing origin and insertion

- **B**
  - Arterial supply to flap
  - Deep palmar artery
  - Branch of deep palmar artery

- **C**
  - Nerve supply to flap
  - Ulnar nerve
**ANATOMY**

**Landmarks**
The muscle forms the bulk of the volar border of the palm, extending from the distal wrist crease to the distal palmar crease. The muscle also forms the main bulk of the hypothenar eminence.

**Composition**
Muscle.

**Size**
$5 \times 1$ to $2$ cm.

**Origin**
Pisiform bone of the distal carpal row.

**Insertion**
Ulnar-volar base of the proximal phalanx of the small finger and dorsal aponeurosis of the extensor digiti minimi.

**Function**
Small finger abduction; expendable.

**Arterial Anatomy**

**Dominant Pedicle**  *Deep palmar artery*

**Regional Source**  Ulnar artery.

**Venous Anatomy**

Venae comitantes of the ulnar artery.

**Nerve Supply**

**Motor**
Deep branch of the ulnar nerve, which penetrates the muscle on its radial deep aspect with the vascular pedicle.
VASCULAR ANATOMY OF THE ABDUCTOR DIGITI MINIMI FLAP

Deep surface of flap

Radiographic view

Fig. 9A-2

Dominant pedicle: Deep palmar artery (D)

FLAP HARVEST

Design and Markings
The muscle forms the bulky prominence of the hypothenar eminence, extending from the pisiform bone of the distal carpal row to the volar base of the small finger radially. Skin is not included in the flap to reduce the risk of painful hypothenar scarring. Incisions are linear or curvilinear.

Fig. 9A-3  Marking for flap incision (dashed line = alternate incision).
Patient Positioning
The patient is placed in the supine position.

GUIDE TO FLAP DISSECTION
The standard flap is raised by incising skin and subcutaneous fat until the volar aspect of the muscle is visualized. Dissection is continued distally to its tendinous insertion, taking care to preserve the neurovascular supply on the deep radial surface of the proximal end of the muscle. The muscle has to be separated from the flexor digiti minimi. Transposition can be performed into the palm or wrist.

Flap after release of insertion  Deep surface of flap  Closeup view of flap base

Coverage of palm (opponens transfer)  Coverage of wrist

Fig. 9A-4
FLAP VARIANT

- Functional muscle transfer: Huber opponensplasty

**Huber Opponensplasty**

The flap is dissected as for the standard approach, but once isolated on its insertion, the muscle has to be tunneled across the palm subcutaneously for insertion into the base of the thumb. A subcutaneous tunnel is made along the proposed axis of pull of the muscle in its new position. The tunnel is made immediately subcutaneously, communicating through a counterincision at the ulnar base of the thumb at the metacarpophalangeal joint. The tendinous insertion of the abductor is woven into and sutured to the tendon of the abductor pollicis brevis only, tensioning the repair to maintain the thumb abducted 90 degrees from the flat plane of the hand to achieve functional opposition of the thumb to the fingers. Lax tension will result in poor opposition.

**Fig. 9A-5**  Huber abductor digiti minimi opponensplasty. Two incisions are required to expose and transfer the abductor digiti minimi muscle. The neurovascular structures enter the muscle proximally on its deep and radial aspect. The muscle is freed from the other hypothenar muscles, and its origin on the pisiform bone is elevated while preserving a tendinous attachment to the tendon of the flexor carpi ulnaris. The abductor digiti minimi is then rotated 180 degrees on its long axis and passed subcutaneously to the area of the thumb metacarpophalangeal joint. The distal attachment is to the abductor pollicis brevis muscle.
ARC OF ROTATION
The muscle can be rotated almost 180 degrees onto the wrist or across the palm.

FLAP TRANSFER
The standard muscle is raised and transposed into a palmar or wrist defect and can be skin grafted to complete closure. The functional Huber transfer for thumb opposition must be tunneled across the palm into its new attachment to the base of the thumb to achieve opposition.

FLAP INSET
For a simple transposition, the muscle is sutured in place with absorbable sutures to anchor the muscle belly in place before skin grafting. For functional muscle transfer, the muscle insertion has to be anchored into the ulnar border of the thumb metacarpophalangeal joint to achieve the direction of pull, facilitating opposition of the thumb.

DONOR SITE CLOSURE
Primary skin closure is possible in all cases.
CLINICAL APPLICATION
This 65-year-old farmer had undergone resection of the ulnar head for the treatment of osteomyelitis of the distal ulna. The dead space and proximal ulnar bone were covered with the use of the ADM flap.

Fig. 9A-7  A, Resection of the ulnar head. B, The flap was harvested through an incision placed at the glabrous-nonglabrous skin junction. The muscle was then used to C, obliterate the dead space and D, skin grafted with an unmeshed split-thickness graft. E, The result is shown at 6 months with irradiation of the infection. (Case courtesy Steven L. Moran, MD.)
Pearls and Pitfalls

- The flap is short and narrow and cannot be used for large palmar or wrist defects.
- Functional transfer requires careful preservation of the neurovascular bundle.
- Careful adjustment of tension is necessary in functional transfer to achieve functional benefit.
- Functional transfer must always be preceded by attainment of full passive range of motion in the recipient thumb’s metacarpophalangeal joint to achieve a useful functional outcome.
- A functional Huber transfer creates a visible thick ridge across the palm initially; this will always be visible to some extent.

EXPERT COMMENTARY

Steven L. Moran

Indications
The adductor digiti minimi muscle is most frequently used as a functional muscle transfer for restoration of thumb opposition in children; this has historically been referred to as the Huber transfer.

Advantages and Limitations
Benefits of adductor digiti minimi muscle transfer have included the ease of dissection and a scar that is well hidden at the glabrous-nonglabrous border of the hand. Other options for opponensplasty in children include the transfer of the superficialis tendon of the ring or long finger to the thumb. For adult patients, oppositional transfer using the superficialis tendon has been shown to more closely approximate the excursion and strength of the native thumb musculature.

However, the muscle suffers from several shortcomings in that the transfer tends to create more thumb flexion than true opposition because of the vector of pull on the thumb. Second, in many cases the muscle with attached tendon is not long enough to adequately reach the thumb metacarpophalangeal joint (specifically, the insertion point of the native abductor pollicis brevis) to allow ideal oppositional tendon insertion. In such cases, an intercalary tendon graft can be harvested from the palmaris longus or another donor tendon.

To avoid tendon grafting one can harvest a portion of the small finger extensor mechanism during muscle harvest to enhance the muscle’s reach.

Recommendations

Technique
Use of the adductor digiti minimi for coverage of open wounds is somewhat antiquated because of the many perforator flaps that can be raised from the wrist and forearm; however, knowledge of its use is still valuable in situations of ulnar head osteomyelitis or where obliteration of the ulnar carpal space is required (see Fig. 9A-7). The majority of the muscle’s bulk is located proximally, limiting its use to defects that lie in the immediate vicinity of the pisiform bone. Additional motion may be obtained by detaching both the insertion and origin of the muscle; however, one must exercise care in these situations, because the pedicle is small and may kink or twist during flap inset.
Bibliography With Key Annotations


Anomalous variations of abductor digiti minimi are commonly found at Guyon’s canal but rarely cause ulnar nerve compression. The authors reported such a case, with particular emphasis on the effectiveness of ultrasound for detecting and delineating anatomic structures in this region.


Soft tissue masses of the foot are rare and present a difficult diagnostic problem. These unusual lesions can be congenital or acquired. The diagnosis is made by imaging and histological examination. When the mass is clinically solid, there is concern about the possibility of a malignant soft tissue tumor. The indication for surgical intervention is based on functional impairment and usually involves ruling out malignancy or ameliorating pain and discomfort. One case of a rare, isolated, congenital hypertrophic abductor digiti minimi of the foot was presented with reference to its clinical picture and treatment.


The authors reported on the use of the abductor digiti minimi myocutaneous (ADM) island flap as an opposition transfer. They concluded that the procedure is easy and safe, and, compared with the Huber transfer, provides more bulge in the thenar area. This procedure may be useful for patients with Blauth grade 2 and 3A hypoplastic thumb.


The authors reported on 10 cases of hypoplastic thumbs treated by abductor digiti minimi opponensplasty. The results of only 9 patients were discussed, however. This operation was combined with Z-plasty to correct narrowing in the thumb-index web space. Adductorplasty using extensor indicis proprius was performed in 6 cases to restore metacarpal phalangeal joint stability in the thumb. The authors’ opponensplasty procedure was modified by transferring the origins of the abductor digiti minimi muscle to the palmaris longus tendon. Follow-up was 1 to 8 years, with excellent results.


Abductor digiti minimi transfer was used to restore opposition in 20 patients, the majority of whom had congenital anomalies of the hand. The transfer was shown to be effective in restoring abduction, but less effective in restoring the rotational component of opposition in these patients. The donor site was critically reviewed and found to be acceptable. The surgical techniques and benefits of this transfer were reviewed.


Three patients with aberrant muscles passing through Guyon’s canal were described. Each of the three patients had, among other symptoms, dysesthesias on the volar aspects of the little and ring fingers. The anomalous muscle in two of these patients arose from the antebrachial fascia just proximal to Guyon’s canal, traveled through the canal, and inserted with the abductor digiti minimi muscle. This anomaly was bilateral in both patients. In the third patient, the abductor digiti minimi muscle originated radially from the transverse carpal ligament, and this variant too was bilateral. Symptoms in each of the three patients resolved after surgery. Ulnar nerve compression at Guyon’s canal is discussed and the literature is reviewed. Although anomalous muscles occur frequently in this location, the anatomic variant found in the third patient had not previously been described in the literature.

In a series of 12 patients incapacitated by persistent or recurrent pain in the palmar aspect of the hand and wrist, successful rehabilitation was aided by employing an abductor digiti minimi muscle flap. It was emphasized that this muscle flap was used as an adjunct to microsurgical internal neurolysis and neuroma resection. Eleven of the 12 patients achieved good to excellent results in terms of relief of pain, plus either return to their previous job or vocational rehabilitation. The “salvage” nature, donor site morbidity, and technical demands of the procedure were emphasized.


Although abductor digiti minimi transfer is a common form of opponensplasty for congenital hypoplastic thumbs, the inclusion of hypothenar skin with this flap, to create a myocutaneous flap, has not been well described. From a series of over 600 index pollicizations and hypoplastic thumb reconstructions performed from 1977 to 2007, the authors presented 14 patients with congenital thumb hypoplasia who had abductor digiti minimi myocutaneous flap transfer to improve thumb opposition. The primary indications for transfer were inadequate thumb opposition and aplastic palmar and thenar soft tissues. Follow-up ranged from 1 to 22 years. All 14 transfers survived and were successful in improving thumb opposition. Key pinch strengths averaged 40% of normal. The inclusion of the skin paddle eliminated routing the muscle through tight palmar soft tissues while improving thenar bulk and appearance.
## ANATOMIC LANDMARKS

| Landmarks | May be used in its entirety or as a partial composite tissue transplantation for thumb reconstruction. It extends from the middle of the first metatarsal to the tip of the great toe and to the mid-portion of the first web space of the foot. |
| Size | Variable; on average, 4 to 5 cm long and 2 to 3 cm wide. |
| Function | Plantar flexion of the distal foot for push-off during ambulation and jumping. |
| Composition | Osteocutaneous, fasciocutaneous. |
| Flap Type | Type A. |
| Dominant Pedicle | Common digital artery arising from the first dorsal metatarsal artery. |
| Minor Pedicle | First plantar metatarsal artery. |
| Nerve Supply | Three sources: the digital nerves, the medial dorsal cutaneous nerve of the superficial peroneal nerve, and the terminal branch of the deep peroneal nerve. |
Section 9B

HAND

Great Toe (Hallux) Flap

CLINICAL APPLICATIONS

Regional Use
Coverage of plantar surface of foot

Distant Use
Reconstruction of thumb and distal phalanx of finger

Specialized Use
Sensate soft tissue coverage in hand
ANATOMY OF THE GREAT TOE (HALLUX) FLAP

**Fig. 9B-1**

**Dominant pedicle:** First dorsal metatarsal artery

**Minor pedicle:** First plantar metatarsal artery
ANATOMY

Landmarks May be used in its entirety or as a partial composite tissue transplantation for thumb reconstruction. It extends from the middle of the first metatarsal to the tip of the great toe and to the midportion of the first web space of the foot.

Composition Osteocutaneous, fasciocutaneous.

Size Variable; on average, 4 to 5 cm long and 2 to 3 cm wide.

Function Plantar flexion of the distal foot for push-off during ambulation and jumping.

Arterial Anatomy (Type A)

Dominant Pedicle First dorsal metatarsal artery (FDMA)

Regional Source Dorsalis pedis artery and associated venae comitantes and saphenous vein.

Length 5 cm.

Diameter 1.5 mm.

Location Immediately distal to the heads of the first and second metatarsal bones, the dorsalis pedis artery bifurcates into the first metatarsal artery and a deep branch into the plantar aspect of the foot. The first metatarsal artery then provides branches to the medial great toe and a common digital branch that bifurcates to the lateral great toe and medial second toe.

Variations of the First Dorsal Metatarsal Artery

Variations in the course, origin, and size of the FDMA have been observed in anatomic studies. The following classification describes the anatomy and frequency of these variations.

Type A (Superficial) (49%) The FDMA originates directly from the dorsalis pedis or from the superficial part of the deep communicating branch. This vessel then courses distally in a superficial plane dorsal to the transmetacarpal ligament.

Type B (40%) In these patients the FDMA arises from the lower part of the deep communicating branch, or it may arise from the deep plantar arch. It lies deep or within the first interosseous muscle and runs distally and dorsally, eventually becoming superficial between the heads of the first and second metatarsal and coursing dorsal to the transmetacarpal ligament.

Type C (11%) In these patients the vessel is very narrow or totally absent, and the blood supply of the great and second toe depends largely on the plantar metatarsal artery.

In type A and type B patients, the FDMA is available for use as the dominant vascular pedicle. In type C patients, the great toe transplant requires use of the first plantar metatarsal artery.

Careful identification of both vessels before pedicle division may obviate the need for preoperative arteriography; however, preoperative arteriography is recommended for evaluation of the great toe circulation if there is a history of prior trauma or congenital anomalies of the foot.

Minor Pedicle First plantar metatarsal artery (FPMA); the FPMA may represent the dominant arterial pedicle to the great toe

Regional Source Deep plantar arch.

Length 6 cm.

Diameter 1 mm.

Location The deep plantar arch is formed by the junction of the lateral plantar artery with the deep plantar branch of the dorsalis pedis artery that courses through the first interosseous space. At the level of the base of the first metatarsal, the FPMA arises from the medial aspect of this plantar arch. The FPMA then sends digital branches to the medial and lateral great toe.
Variations in the Dorsal and Plantar Arterial Circulation to the Great Toe

Two communications exist between the dorsal and plantar arterial circulations. Between the heads of the first and second metatarsals, the deep plantar artery communicates with the dorsalis pedis artery and the plantar arch. A dorsal distal perforating artery joins the dorsal and plantar metatarsal arteries near their bifurcation.

Several variations of the distal perforating artery exist. In the most common variant (46%), it arises from the FDMA and splits into two plantar digital arteries (PDAs). In 24% of patients, the distal perforating artery communicates between the bifurcations of the FDMA and FPMA. In 15% of patients, the FPMA gives rise to two PDAs, one of which is joined by the distal perforating artery. In a small percentage of patients, the distal perforating branch may be absent or small communicating branches will exist between the dorsal digital arteries (DDAs) and PDAs.

Venous Anatomy

Venae comitantes follow the arterial branches. Associated superficial veins that drain the first web space and great toe join to form the saphenous vein.

Nerve Supply

Sensory

Three sources: the digital nerves, the medial dorsal cutaneous nerve of the superficial peroneal nerve, and the terminal branch of the deep peroneal nerve.
Vascular Anatomy of the Great Toe (Hallux) Flap

Dominant pedicle: First dorsal metatarsal artery (D)
Minor pedicle: First plantar metatarsal artery (m)
e, Extensor pollicis longus; f, flexor pollicis longus; n₁, dorsal digital nerve; n₂, plantar digital nerve; v, superficial vein

Fig. 9B-2

First dorsal interosseous space
Dorsal surface of flap
Radiographic view
FLAP HARVEST
Design and Markings

The great toe is examined for size and shape and compared with the second toe. If it is excessively wide or curved, this may affect its suitability for transplantation as a composite flap for thumb reconstruction.

The medial first web space and dorsalis pedis flap (10 by 8 cm) may be included with the great toe transplant, but this is rarely necessary. Generally, minimal foot skin is included with the great toe to ensure direct donor site closure. A dorsal triangular flap measuring 4 by 3 cm and a smaller plantar triangular flap with the base of the flap oriented at the level of the first metatarsophalangeal (MTP) joint may be included with the great toe transplant.

A chevron-shaped incision is designed with a longer dorsal than plantar skin island. At the apex of the dorsal incision proximally, the marking is extended up the dorsum of the foot as a curvilinear incision, with its long axis over the first metatarsal and web space. The most proximal limit of the marking is at the level of the distal extent of the extensor retinaculum. With the foot in a dependent position over the edge of the operating table, the dorsal venous system is allowed to fill and the dorsal venous arch and saphenous system can be accurately marked.

Fig. 9B-3
Patient Positioning
The patient is placed in the supine position with the lower donor extremity prepared to the midthigh to allow knee flexion and external hip rotation for exposure of the plantar surface of the foot during this portion of the foot dissection.

GUIDE TO FLAP DISSECTION
All dissection is done under tourniquet control, because a bloodless field is essential. A circumferential incision is made at the level of the MTP joint, with the dorsal and plantar triangular flaps that connect with a long dorsal vertical incision extending to the midtarsal region and a shorter plantar incision extending to the level of the MTP joint. A separate medial posterior plantar incision is necessary to expose the proximal flexor hallucis longus tendon.

The proximal incision is extended over the dorsum of the foot to expose the dorsal venous arch and greater saphenous vein. The branches to the second toe and communicating branch to the deep venous system are ligated, isolating the venous outflow to the superficial system only.
The extensor hallucis brevis tendon is identified and divided lateral to extensor hallucis longus. The extensor hallucis brevis is reflected laterally to expose the dorsalis pedis vessels and deep peroneal nerve. The dorsalis pedis artery is traced distally to identify the FDMA at the proximal limit of the first intermetatarsal space. The caliber of the FDMA is evaluated, and if it is greater than 1 mm, the flap can be raised on this vessel. If the vessel is diminutive, however, it will be necessary to use the FPMA.
Assuming an adequate FDMA, the deep plantar artery is then ligated, isolating the great toe on the dorsalis pedis–FDMA pedicle. The extensor hallucis longus tendon is then divided proximally, depending on the length requirement for extensor tendon at the recipient site. The dorsal interosseous muscle is divided to allow further distal dissection of the vascular pedicle based on the FDMA. The branch to the second toe is divided, and the deep transverse metatarsal ligament between the MTP joints of the great and second toes is divided.

Fig. 9B-4
Plantar dissection begins with a chevron incision that is extended for a short distance proximally between the first and second metatarsal heads. The lateral and medial plantar digital nerves and the plantar digital arteries to the lateral aspect of the great toe and medial aspect of the second toe are found lying deep to the divided transverse metatarsal ligament. The flexor hallucis tendon is identified and dissected proximally. Once an adequate length has been exposed, it is divided together with the plantar digital nerves and vessels. At this point the MTP joint can be disarticulated; the toe is now attached only by its dorsal arterial inflow and venous outflow structures. The tourniquet is released, the adequacy of perfusion to the toe can be assessed, and hemostasis is secured at the donor site.
If the patient has a loss of first metacarpal length in the recipient site in the hand, the surgeon will need to harvest additional metatarsal bone proximal to the MTP joint. This is usually done with an osteotomy through the metaphysis of the first metatarsal proximal to the metatarsal head. It is usually performed obliquely at a 60-degree angle from dorsal to plantar, taking more dorsal bone than plantar bone. The angle is important to allow further flexion of the thumb reconstruction, because the great toe has more extension than flexion function compared with the function of the thumb metacarpophalangeal joint. By canting the joint reconstruction into a more volar position on the recipient metacarpal, the reconstructed thumb is better able to achieve opposition and flexion into the palm.

**FLAP VARIANTS**

- Wrap-around flap
- First dorsal web space sensory cutaneous flap

**Wrap-Around Flap**

**Standard Wrap-Around Flap**

The wrap-around flap concept includes elevation of lateral great toe skin and toenail, with preservation of medial toe skin and underlying phalangeal bones for hallux reconstruction. The flap involves harvest of the lateral three-quarter circumference of the toe skin together with an appropriate width of nail and nail bed. The nail of the great toe is usually substantially wider than that of the thumb nail, and this procedure allows a smaller amount of nail width to be harvested to give a better cosmetic match to the normal thumb.
**DESIGN AND MARKINGS**

The width of the required nail is measured and the medial limit of the flap is drawn proximally as a straight line along the dorsum of the great toe at the juncture of its medial third and lateral two thirds. At the level of the MTP joints, marking is extended transversely laterally to the midpoint of the dorsum first webspace. The markings are then carried down the middle of the first web space onto the plantar aspect of sole until the level of the MTP joint is reached again. The markings are next carried medially transversely over the sole at the level of the MTP joint to the midlateral line. Markings continue forward around the tip of the great toe on its volar aspect and are curved upward to meet the lateral edge of the nail fold. They are then carried transversely across the distal edge of the nail bed until they reach the demarcation point of the planned longitudinal split in the nail. As with a great toe transfer, a proximal curvilinear incision is extended up the dorsum of the foot.

**FLAP DISSECTION**

As with great toe harvest, the dorsal greater saphenous vein, dorsalis pedis, and FDMA arterial circulation and the deep peroneal nerve are dissected after dividing and reflecting the extensor hallucis brevis tendon.
Because the tissue is being used as a soft tissue cover without requiring bone or tendon, the extensor hallucis longus tendon is not divided. The first dorsal interosseous muscle is divided and the deep perforating branch is preserved, allowing distal dissection of the FDMA to the level on the deep transverse metatarsal ligament.

Dissection then commences on the plantar aspect. The medial plantar digital artery and nerve are identified and preserved to supply the medial skin bridge which has been left attached to the phalanges of the great toe. The lateral PDA and digital nerve are dissected proximally. The plantar skin is then raised from medial to lateral toward the first web space, leaving a vascularized layer of fat to cover the bones and tendons of the toe. The lateral PDA can be divided as proximally as possible once release of the tourniquet has confirmed that perfusion is adequate to the wrap-around harvest.

When dissecting the FDMA, the deep transverse metacarpal ligament is left intact. Care should be taken at this point to ensure that communication is preserved between the distal perforating artery and its dorsal and plantar derivatives.

The flap can then be harvested and its donor site covered with a full-thickness skin graft. The segment of retained medial nail and nail bed at the donor site should be resected before grafting.
**Modified Wrap-Around Flap**

The technique for the modified wrap-around flap is the same as that described earlier, with the addition of the following maneuvers.

Having isolated the medial skin on its neurovascular pedicle, it remains attached to the underlying bony structures. The modified wrap-around flap incorporates the addition of the distal phalanx within the construct. The proximal skin can be dissected off the paratenon of the extensor hallucis longus and the proximal phalanx that is left adherent to the distal phalanx that is disarticulated through the interphalangeal joint capsule.

The medial nail fragment and its associated nail bed and germinal matrix are completely resected. The medial skin is dissected off the front of the toe down to the midportion of the proximal phalanx, preserving its medial PDA and digital nerve content intact.

The distal half of the proximal phalanx is then resected and the proximally based medial skin flap is draped over the osteotomy site and sutured down to the plantar skin. The dorsal defect is covered with a small split-thickness skin graft, as needed.

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**Fig. 9B-7**

The medial nail fragment and its associated nail bed and germinal matrix are completely resected. The medial skin is dissected off the front of the toe down to the midportion of the proximal phalanx, preserving its medial PDA and digital nerve content intact.

The distal half of the proximal phalanx is then resected and the proximally based medial skin flap is draped over the osteotomy site and sutured down to the plantar skin. The dorsal defect is covered with a small split-thickness skin graft, as needed.
First Dorsal Web Space Sensory Cutaneous Flap

The web space between the great and second toes may be elevated as a neurosensory flap based on the FDMA and associated venae comitantes and branches of the superficial and deep peroneal nerves.

The proposed web space flap is outlined. An initial dorsal incision is made between the first and second metatarsal bones to the level of the midtarsal region. Superficial draining veins to the lateral dorsal great and second toes are preserved. An incision through the extensor retinaculum inferior to the extensor hallucis brevis muscle readily reveals the deep peroneal nerve and first dorsal metatarsal artery. If the FDMA is absent, the flap dissection is stopped and alternate donor sites are selected. If the pedicle is available, distal dissection is completed to the area of the proposed web space flap. The flap edges are incised. At the plantar edge of the flap, the plantar digital artery and nerves are not included with the flap. The flap is elevated superficial to the proximal phalangeal periosteum and to the level of the first transmetacarpal ligament. The flap dissection is connected to the previous dissection of the FDMA and associated venae comitantes, lateral dorsal metatarsal nerve, and superficial draining veins. The tourniquet is released and flap perfusion confirmed. The island flap is ready for transposition to the defects on the plantar surface of the foot or for transplantation as a neurosensory fasciocutaneous flap.

![Flap design](image1)

**Fig. 9B-8**

![Elevation of flap](image2)
ARC OF ROTATION

Standard Flap

The web space flap based on the FDMA with associated branches of the superficial and deep peroneal nerve may be elevated to the level of the dorsalis pedis artery and associated venae comitantes and superficial veins and transposed with a wide arc of rotation to the plantar surface of the foot or ankle.

Plantar skin elevated on the FPMA has an arc of rotation to the plantar aspect of the foot.

**Extension of Pedicle Length**

The FDMA is dissected superior to the level where the extensor hallucis brevis muscle and tendon cross the proximal second metatarsal bone. The deep communicating branch to the plantar arch is located in the proximal first metatarsal space. The FDMA continues superiority at the division of the communicating branch as the dorsalis pedis artery. At the ankle level the dorsalis pedis artery continues superiorly as the anterior tibial artery. Proximal dissection of the anterior tibial–dorsalis pedis–first dorsal metatarsal arterial system is performed as required to obtain an adequate pedicle length for great toe transplantation or transposition of the first dorsal web space neurosensory flap.
If the FDMA is rudimentary or absent, the great toe transplantation is based on the dominant FPMA. This artery is initially isolated in the distal plantar first metatarsal space. The artery may be dissected proximally beneath the flexor hallucis longus tendon and then laterally between the head of the flexor hallucis brevis muscle, where the artery joins the deep communicating branch from the dorsalis pedis artery to form the deep plantar arch.

**FLAP TRANSFER**

The first dorsal web space neurosensory flap is rotated 90 to 180 degrees, as required, to cover the defect. A wide tunnel is necessary, particularly if the flap is designed to reach the plantar surface of the posterior foot.

**FLAP INSET**

**Standard Great Toe Transplant to Thumb Position**

**Bone**

The proximal phalanx or the first metatarsal head of the great toe is initially fixed to the proximal phalanx or first metatarsal bone in the hand. Volar angulation of the metacarpal head allows better opposition and flexion angle. Osteosynthesis is accomplished with cross Kirschner wires, longitudinal Kirschner wires, interosseous wire loops, bone pegs, mini-plates, or a combination of the above.

**Fig. 9B-10**
Nerve Repair
Medial and lateral dorsal sensory nerves are repaired with the dorsal branches of the radial nerve. Medial and lateral plantar sensory nerves are repaired with the digital nerves. If the volar digital nerves are not present at the thumb position, other recipient sensory nerves include the sensory branches of the radial nerve, palmar cutaneous branch of the median nerve, and dorsal sensory branch of the ulnar nerve.

Vascular Repair
An arterial anastomosis is performed between the first dorsal metatarsal or dorsalis pedis artery and the radial artery or princeps pollicis branch. A venous anastomosis is performed between the superficial draining vein and appropriate dorsal veins at the hand recipient site.

Tendon Repair
The flexor hallucis longus tendon is repaired with a flexor pollicis longus tendon. The repair is performed proximal to the transverse carpal ligament within the distal wrist. The extensor hallucis longus tendon is repaired with the extensor pollicis longus tendon. A weave tendon repair is used for both the flexor and extensor tenorrhaphies. The tension is adjusted to ensure thumb flexion with passive wrist extension and thumb extension with passive wrist flexion.
Closure
The skin is closed using the dorsal and volar triangular flaps interposed with skin flaps on the recipient hand. Skin grafts may be required to complete closure, particularly on the lateral and medial aspects of the transplanted toe.

Tenorrhaphy: Extensor hallucis longus to extensor pollicis longus tendon

Tenorrhaphy: Flexor hallucis longus to flexor pollicis longus tendon

Fig. 9B-13

Wrap-Around Flap
The wrap-around flap is inset as described for the standard flap. If this flap is designed as an onychocutaneous flap, an iliac bone graft is initially inset in the hand metacarpal bone. The wrap-around flap is loosely sutured in place over the bone graft. The subsequent repair sequence inset is similar to the previous description for standard great toe transplantation.

Iliac bone graft before wrap-around flap

Composite wrap-around flap inset over bone graft

Closure technique

Fig. 9B-14
First Dorsal Web Space Cutaneous Sensory Flap

**Microvascular Transplantation**

The web space flap is sutured into the defect. A suitable recipient nerve is isolated for repair with the dorsal lateral metatarsal nerve. An arterial vascular anastomosis is performed between the FDMA and the recipient artery and superficial draining vein and appropriate recipient veins.

**Transposition Flap**

The first dorsal web space flap is sutured into the defect, avoiding excessive tension on its vascular pedicle, the dorsalis pedis artery, and associated venae comitantes.

**DONOR SITE CLOSURE**

**Standard Great Toe Transplant**

With preservation of medial foot skin over the first MTP joint region, the donor site can generally be closed directly. If a dorsal defect persists, skin grafts are used. If a plantar defect persists, a second cross-toe flap is required.

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**Fig. 9B-15**

A: Donor site defect  
B: Closure technique
Wrap-Around Flap
A combination of skin graft and second cross-toe flap are used to close the defect on the dorsal and lateral aspect of the remnants of the great toe.

![Diagram of Wrap-Around Flap](image)

Modified Wrap-Around Flap
The distal medially based flap is wrapped over the proximal phalangeal base stump, and a full-thickness skin graft is used to cover the lateral aspect of the defect.

![Diagram of Modified Wrap-Around Flap](image)

First Dorsal Web Space Cutaneous Sensory Flap
The donor site requires skin grafts for closure.
CLINICAL APPLICATIONS
This 40-year-old carpenter had a traumatic amputation of the left thumb 2 years before he presented for reconstruction.

Fig. 9B-18  A, Dorsal and B, volar appearance of the proximal thumb preoperatively. C, The trimmed toe was designed from the nondominant foot. The pedicle position is easier if the toe can be harvested from the ipsilateral foot. However, it is more important to harvest from the nondominant foot. D, Dissected trimmed toe. E, Harvested trimmed toe.
Fig. 9B-18  **F,** Exposed proximal stump of the amputated thumb, all structures identified for reconstruction.  **G,** Dissected princeps pollicis artery.  **H,** The results are seen at 1 year postoperatively with opposition of the thumb to the ring finger,  **I,** the thumb’s dorsal appearance and flexion, and  **J,** the thumb’s volar appearance and extension and abduction. (Case courtesy Milan Stevanovic, MD.)
The right hand of this 27-year-old machinist was caught in a machine belt. He sustained a crush-avulsion injury, with avulsion of the soft tissue and nail of the distal phalanx of the thumb.

**Fig. 9B-19**  
A, Distally based dorsal soft tissue avulsion.  
B, Volar soft tissue injury at presentation.  
C, Dorsal soft tissue after debridement of necrotic tissue.  
D, Dorsal and E, volar appearance of the thumb after debridement.  
F, Dissected wrap-around flap.  
G, Harvested wrap-around flap.
**Hand**

9B: Great Toe (Hallux) Flap

Fig. 9B-19  **H,** Dorsal and **I,** volar intraoperative views of reconstruction. **J,** At 14-month follow-up, satisfactory abduction and extension of the thumb can be seen. **K,** Flexion and opposition of the reconstructed thumb. **L,** Comparative appearance to the contralateral thumb in flexion, and **M,** comparative appearance to the contralateral thumb in extension. (Case courtesy Milan Stevanovic, MD.)
Pearls and Pitfalls

- Variations in the FDMA must be taken into account in planning the flap.
- A type C variation of the first dorsal metatarsal artery is a contraindication to the use of a first dorsal web space flap. Preliminary identification of the FDMA is required before flap elevation.
- The use of a tourniquet during flap elevation is recommended. Before division of the vascular pedicle to the great toe or first web space flap, the tourniquet is released and great toe or flap perfusion observed for 15 to 20 minutes to ensure that circulation is adequate before transplantation.
- The first metatarsal head or plantar aspect of the metatarsal head should be preserved to improve donor site function by maintaining bone length for push-off during ambulation.
- Length and positioning of the great toe are important for function and appearance. The average thumb length extends to the proximal interphalangeal joint of the index finger. Exact length measurements can be obtained from the contralateral thumb, if present. The great toe is rotated for pulp contact with the index and little fingers on thumb abduction and opposition.
- In a child, the proximal phalangeal epiphyses are preserved to ensure finger growth.
- If the MTP joint is included with the great toe, bone fixation with the hand metacarpal bone should avoid hyperextension at the great toe MTP joint. This is avoided by performing an oblique 45- to 60-degree angle osteotomy at the distal metatarsal bone, depending on the degree of flexion available in the donor MTP joint. A lesser degree of flexion at the joint requires a 45-degree osteotomy to tilt the joint into a more palmar angle for flexion on the hand.
- Alternate recipient structures in the hand include use of the extensor indicis proprius if the extensor pollicis longus tendon is unavailable; use of the long or ring finger digitorum sublimis if the flexor pollicis longus is unavailable; and use of the volar digital nerve of the long or ring finger if the thumb volar digital nerves are unavailable.
- If possible, the sensory nerves should be repaired before great toe revascularization to allow optimal visualization of the nerve ends in a bloodless field.
- Appropriate balance between the extensor and flexor tendon repair is essential. Initial repair of the extensor tendon is accomplished to allow thumb extension with 90-degree wrist flexion. The subsequent flexor pollicis longus tendon repair is adjusted to provide mild great toe interphalangeal and MTP joint flexion with passive wrist extension.
EXPERT COMMENTARY

Milan Stevanovic

Indications
The first successful thumb replantation was reported by Tamai, Komatsu, and colleagues in 1967,1 and today surgeons make every effort to save an amputated thumb. When the thumb cannot be salvaged, transfer of the great toe to the thumb provides the best functional and cosmetic restoration of this critical part of the hand anatomy. There are several techniques of great toe transfer, depending on the level and extent of thumb loss. The different techniques include great toe transfer, trimmed toe transfer, partial toe transfer, and a wrap-around procedure.

Recommendations

Planning
The great toe transfer provides the best pinch and grip power of any reconstruction. However, this procedure is now rarely used because of the cosmetic appearance of the reconstructed thumb, which appears overly large and bulbous. Although the size of the pulp can be reduced, the transferred toe always appears much larger than the contralateral thumb.

The trimmed toe transfer is now the most commonly performed reconstruction. This procedure provides nearly the same functional outcome as the great toe transfer, but it produces a markedly improved cosmetic appearance.

Partial toe transfers are indicated only for reconstruction of the distal phalanx and interphalangeal joint.

The wrap-around procedure was widely performed after its introduction. It was commonly used to cover nonvascularized iliac crest bone graft. At its best outcome, it provided a good cosmetic outcome, but the result was not as functional as a great toe or trimmed great toe transfer. The complications of bone resorption and nail deformity were common and led to the recommendation that the wrap-around only be used in cases of skeletonization of the thumb with intact bone and tendon, but absent skin and nail.

With great toe, partial toe, and trimmed toe transfers, the flexor and extensor pollicis longus should be reconstructed along with three sensory nerves: two plantar nerves for reconstruction of the radial and ulnar digital nerves, and one dorsal nerve to reconstruct a branch of the superficial radial nerve.

Technique
The incision for harvest of the great toe should begin in the first web space. I prefer a V-shaped incision around the great toe rather than a racket incision. This minimizes the constriction of circumferential scarring of the newly created thumb.

The princeps pollicis artery should always be used as the recipient artery for the first dorsal metatarsal artery, which supplies the great toe. Approximately 50% of the time, the first dorsal metatarsal artery lies on the dorsal side of the foot within the first intermetatarsal space and first web space. The other 50% of the time, the first dorsal metatarsal artery dives plantarward and follows the intermetatarsal space plantar to the midaxis of the metatarsal. This anatomy requires more difficult dissection and a plantar incision to expose and harvest this vessel.

The best veins for the great toe are located medially. The veins are better identified when the leg has not been exsanguinated with an Esmarch tourniquet, but rather exsanguinated with gravity elevation.

Continued
The dissection of the great toe, including division of tendons, nerves, and bone (or capsule), should be completed. The artery and veins are left intact. The tourniquet is released and the toe is allowed to perfuse for at least 20 minutes before completing the toe harvest.

**Take-Away Messages**

The toe from the nondominant foot should be selected for transfer. A Doppler study of the first dorsal metatarsal artery should be done to confirm an adequate pedicle to the great toe. The great toe should not be used if the patient has had a previous injury to that foot. The length needed for the reconstructed structures must be measured to avoid using grafts (plantar nerves, first dorsal metatarsal artery, and tendons).

**Reference**


**Bibliography With Key Annotations**


- A review of replanted digits indicated that excellent sensory function can be recovered in replants that are distal, in which the mechanism of injury has been a sharp cut, in which the patient is young, and in cases in which the patient receives postoperative sensory reeducation. It appears that poor sensory recovery in replanted digits is most directly attributable to crush or avulsion-type injuries and lack of sensory reeducation in the postoperative period.


- The authors reported a retrospective review of their series of 31 single joints harvested from the toe in 26 patients and transferred to the metacarpophalangeal or proximal interphalangeal joint of the finger. Twenty-six cases were traumatic and 5 were congenital. Follow-up averaged 22.6 months. The authors concluded that vascularized joint transfer provides a reasonable alternative to arthrodesis and with further refinement in technique may become a reliable treatment option.


- The traumatic amputation of the thumb is an absolute indication for attempted replantation. The profound disability of the hand resulting from absence of the thumb, with loss of pinch and grasp, obliges the surgeon to make every attempt to replant the amputated thumb and preserve hand function. However, not all attempts at replantation result in survival of the amputated portion, and unreconstructable damage to or complete loss of the amputated part may preclude attempted replantation. In such situations, the surgeon must have alternative methods of dealing with the sequelae of thumb loss. This article discussed nonmicrosurgical and microsurgical techniques for thumb reconstruction.


- The authors presented their experience with partial or total toe transfers for the reconstruction of finger deficits. Sixty-one toes were transferred to reconstruct finger deficits in 60 patients. The transfers from the big toe consisted of vascularized whole-nail grafts, onychocutaneous flaps that included the nail and a skin flap from the toe tip, thin osteonychochalaneous flaps, wrap-around flaps, and combined wrap-around and dorsalis pedis flaps. The transfers from the second toe consisted of trimmed toe tips...
including the nail, second toes, a combined second toe and dorsalis pedis flap, and a second toe and third toe. The other transfers mainly consisted of other flaps, including a hemipulp flap and a first web space flap. Regarding the transfers from the big toe, vascularized nail grafts and onychocutaneous flaps were found to be most suitable for the treatment of total nail loss, thin osteoonychocutaneous flaps for distal phalangeal loss of the thumb, wrap-around flaps with a vascularized iliac bone graft for thumb loss above the metacarpal joint, and the combined wrap-around and dorsalis pedis flaps for a total thumb deficit. For transfers from the second toe, the trimmed toe tips including the nail were most suitable for claw nail deformities, the second toe was most suitable for finger loss, except for the thumb with the proximal interphalangeal joint, and the combined second toe and dorsalis pedis flap was most applicable for a total thumb deficit, including the thenar skin loss.


Toe-to-hand transplantation has become a well-established method for function and appearance reconstruction after trauma and in congenital hand anomalies. An otherwise healthy and cooperative patient is the ideal candidate for toe transplantation after trauma. In such a patient, even primary toe transplantation is possible, if the stump is clean and viable. If secondary reconstruction after completed wound healing is considered, emphasis should be laid on tissue sacrifice during the acute management of nonreplantable amputations of the hand. Specific considerations regarding selection of toes to be transplanted, technique of toe harvest and inset, sequence of transplantations if more than one digit is to be reconstructed, such as in the metacarpal hand, and postoperative regimen are important to achieve satisfying functional and aesthetic results on both recipient and donor sites. A trimmed great toe is ideal for thumb reconstruction if the amputation is located at or distal to the middle metacarpal shaft. However, in more proximal amputations, a second toe may be more suitable, because it allows transmetatarsal harvest without increasing donor site morbidity. Distal finger reconstruction with partial toe or second toe wrap-around flap gives the most gratifying result to those patients who are critically concerned about their body image and also those who need distal fingers for their occupations or recreational activities. Combined second and third toe or third and fourth toe transplantations are particularly useful in metacarpal hand reconstruction to provide tripod pinch.


To identify an anatomically reliable and functionally acceptable neurovascular free flap for use in hand reconstruction, 50 fresh cadaver feet were dissected under the operating microscope, with particular attention to the anatomy of the first web area. A distal communicating artery was seen in 100% of dissections, allowing either dorsal or plantar donor artery inflow to nourish the entire flap area. Because of the ease of dissection, the first dorsal metatarsal or dorsalis pedis is suggested as the donor artery, and a dorsal branch of the greater saphenous venous system is suggested as the donor vein. The deep peroneal nerve was seen to consistently innervate the first web and, along with the plantar digital nerves, is suggested as an anatomically identifiable donor nerve. Either part of the foot first web may be used alone or together as a free flap. When indicated further dorsal skin may be incorporated into the web flap to expand its application. Two-point discrimination studies of the lateral plantar surface of the great toe in 50 normal individuals showed an average of 11.2 mm. This was significantly better as a potential donor flap than the medial dorsum of the foot where the average was 32 mm. A single case demonstrating the application of this flap in hand reconstruction was presented.


Thumb reconstruction requires accurate functional and aesthetic approximation to the original. Accepted methods generally have some deficiencies, particularly in appearance, and frequently the secondary morbidity is unacceptable. A method of thumb reconstruction with the use of an iliac crest bone graft and a free neurovascular wrap-around flap from the great toe was described that combines the attributes of previous methods without their secondary morbidity.

The authors presented two cases of degloving injuries of the thumb, with amputation of the distal phalanx. In the first case, an osteocutaneous flap was transferred from the first toe, providing effective thumb function. In the second case, a fasciocutaneous interosseous flap was placed around the segment of the exposed thumb, with a satisfactory result.


The authors examined and evaluated the reconstructed thumb and donor foot morbidity of 69 patients who had thumb reconstruction with a modified wrap-around flap. Donor morbidity was assessed subjectively and objectively using the Foot Function Index verbal rating scales in 34 patients, the American Orthopaedic Foot and Ankle Society’s hallux metatarsalphalangeal-interphalangeal (MTP-IP) scale in 34 patients, and gait analysis and dynamic pedodynographic measurements in 20 patients. Follow-up ranged from 6 months to 5 years. The aesthetic appearance of the reconstructed thumbs was good. The full length or most of the length of the donor toes was preserved in 67 patients. The FFI-5pt total score was 3.1, and the total hallux MTP-IP score was 87.9. No significant difference was measured in any of the five biomechanical parameters (timing, trajectory, symmetry, average peak force, and peak pressure between donor foot and the contralateral foot). The function of the donor foot was well preserved, with only mild pain and disability. Foot function in gait was not affected. Restriction in interphalangeal joint motion was almost negligible.


When replantation of an avulsed/amputated thumb is not feasible, toe-to-hand transfer may be considered as a reconstructive option in appropriately chosen patients. Although selection criteria are purposefully restrictive, immediate one-stage transfer, as opposed to a delayed procedure, provides many advantages. Primary reconstruction reduces hospitalization and operative and recovery time. It also may expedite return of function and allow patients to return to work sooner. The ability of the patient to undergo extensive microvascular reconstruction at the time of injury, the psychological preparation required, and the need to understand potential risks are important factors to consider. Six patients with thumb amputations underwent immediate great toe-to-hand transfer. The overall results of these thumb reconstructions were evaluated retrospectively with regard to function, outcome, length of stay, complications (infection, contracture, or need for reexploration), and time to return to work/normal activity. All patients were laborers who sustained work-related avulsion-amputations. No complications were reported during initial hospitalization, lasting an average of 12 days. Donor site morbidity was minimal. The data suggest that thumb reconstruction using great toe transfer can be safely and reliably performed during the initial presentation in selected patients. The economic and therapeutic advantages should be weighed against the risks associated with this approach when evaluating thumb avulsion-amputations.


Microsurgical toe transfer is an established method for reconstruction of missing thumbs. However, there is little agreement on which of the various techniques represents the ideal transfer. Basically, selection of technique requires balancing the patient’s functional needs, appearance of the reconstructed thumb, and donor site cosmesis. Based on their experience with 103 toe-to-thumb transfers performed over the past 9 years, the authors provided guidelines for appropriate selection among the four most commonly employed toe transfer techniques (second toe, total great toe, great toe wrap-around, trimmed great toe) so that optimal results and patients’ acceptance can be achieved.


Techniques for aesthetic refinement are as important as those for functional improvement in toe-to-hand transfer. The appearance of the thumb reconstructed using various types of great toe transfer can be improved by reduction of the soft tissue, bone, interphalangeal joint, and nail and by secondary...
pulp reduction and contouring procedures. Finger and thumb reconstructions using lesser toes can be improved aesthetically by minimal inclusion of adipofibrous tissue under the plantar skin flap, especially at the metatarsophalangeal joint region, thus decreasing the anterior-posterior bulkiness. Tight extensor repair and temporary K-pin fixation of the proximal and distal interphalangeal joint in extension, followed by prolonged use of a nighttime extension splint and secondary pulp reduction, will help to avoid the claw and drumstick appearances of the transferred lesser toe. Adequate soft tissue coverage, cruciate skin incisions, extensive mobilization, and thinning and trimming of the skin flaps of the digital amputation stump lead to a smooth junction between the amputated digit and the transferred toe. In the distal digital reconstruction, skeletonization of medial and lateral neurovascular bundles of the harvested toe helps primary closure of the digital wound, thus avoiding the unsightly skin graft on the sides of the reconstructed digit. Regarding the donor foot, preservation of the proximal 0.5 to 1 cm of the proximal phalangeal stump of the great toe maintains the span of the foot, thus improving donor site appearance. In single lesser toe or combined second and third toe transfer, the proximal phalanx should not be preserved but an optimal web space should be reconstructed. Primary closure without a skin graft is essential for aesthetic appearance of the donor foot.


In a mutilated hand, microsurgical toe-to-hand transplantation provides thumb and finger reconstruction that is superior to conventional techniques in appearance and function. Hand reconstruction using toe transplantation should be individually planned and carefully executed to obtain optimal results and minimal disability in the donor foot.


Pulp plasty is a simple procedure that is used to debulk the bulbous-appearing pulp of a transplanted digit after toe-to-hand transplantation. A retrospective review of the effect of pulp plasty on the appearance and function of the debulked digit was conducted on 82 digits on 51 patients. Pulp plasty was performed on average of 14 months after toe-to-hand transplantation. The average follow-up was 20 months. Subjective improvement in appearance and function was reported in 67.1% and 63.4%, respectively, of the debulked digits. Painful scarring was rare, and hypersensitivity was not reported. Sensation was not affected adversely by pulp plasty. The procedure was considered to be worthwhile in 87.8 percent of the cases. Pulp plasty is a simple and effective procedure after toe-to-hand transplantation that enhances the appearance and function of the transplanted digit. Patient satisfaction with the procedure is high.


The authors introduced a single-stage method of reconstructing bilateral defective thumbs with various toe-tissue configurations in five patients. These include two bilateral second-toe transfers, one bilateral hallux wrap-around flap transfer, one bilateral modified hallux wrap-around flap transfer, and one combination of second toe with island flap and neurovascular pedicles from the proximal and dorsal aspect of the index finger. Eight transferred tissues survived uneventfully, and two had temporary circulation problems. After 1 year, the appearance was satisfactory and function was excellent in all cases. The authors stressed the importance of a double artery supply and venous return flow system.


Thumb and donor foot function were evaluated in 65 patients who had thumb reconstruction with a modified wrap-around flap. Twelve patients had skin-degloving injuries and late class IB defects, 44 patients had class II defects, and 9 had class IIIA defects. Function was evaluated in 20 patients using the Foot Function Index verbal rating scales (FFI-5pt), the American Orthopaedic Foot and Ankle Society’s hallux metatarsophalangeal-interphalangeal (MTP-IP) score, and gait analysis and dynamic pedobarography. Follow-up ranged from 6 to 60 months. The reconstructed thumbs had an aesthetic appearance and satisfactory range of motion. The authors concluded that the modified wrap-around flap can achieve aesthetic and functional thumbs, preserving most of the function of the donor feet.
ANATOMIC LANDMARKS

Landmarks
Ulnar or radial aspect of the digit based ipsilateral to the longest fingertip amputation flap. Flap extends from the distal tip of the finger to the proximal digital crease. Flap is designed over the volar lateral aspect of the digit. A straight midaxial line is marked on the side of the finger with the longest skin flap relative to the distal amputation. The base of the triangle corresponds to the width of the amputation tip, and the oblique arm of the flap is carried in a volar oblique and proximal direction to reach the midaxial line. This point forms the apex of the flap, which is found either at the proximal interphalangeal joint or more proximally at the proximal digital flexion crease. When used to resurface the thumb, the skin island is usually based on the ulnar aspect of the ring finger.

Size
Length of the flap is 2.5 times the width; varies according to how much advancement is required to cover the defect.

Flap Type
Type A.

Dominant Pedicle
Digital artery.

Minor Pedicle
Includes small perforators from the digital artery, which can be seen along the length of the digital artery.

Nerve Supply
Digital nerve is incorporated within the flap.
Section 9C

HAND

Homodigital Neurovascular (Littler) Island Flap

CLINICAL APPLICATIONS

Regional Use

Resurfacing of the thumb pulp or the radial surface of the index finger with sensate glabrous skin

With contributions by Michel Saint-Cyr, MD.
ANATOMY OF THE HOMODIGITAL NEUROVASCULAR (LITTLE) ISLAND FLAP

**Fig. 9C-1**

**Dominant pedicle:** Digital artery

- **A** Bony architecture of hand
- **B** Digital artery
- **C** Relationship of blood supply to underlying skeleton
- **C** Nerve supply to hand
ANATOMY

Landmarks  Ulnar or radial aspect of the digit based ipsilateral to the longest fingertip amputation flap. Flap extends from the distal tip of the finger to the proximal digital crease. The flap is designed over the volar lateral aspect of the digit. A straight midaxial line is marked on the side of the finger with the longest skin flap relative to the distal amputation. The base of the triangle corresponds to the width of the amputation tip, and the oblique arm of the flap is carried in a volar oblique and proximal direction to reach the midaxial line. This point forms the apex of the flap, which is found either at the proximal interphalangeal joint or more proximally at the proximal digital flexion crease. When used to resurface the thumb, the skin island is usually based on the radial aspect of the ring finger.

Composition  Fasciocutaneous.

Size  Length of the flap is 2.5 times the width; varies according to how much advancement is required to cover the defect.

Arterial Anatomy

Dominant Pedicle  Digital artery

REGIONAL SOURCE  Superficial palmar arch.

LENGTH  4 to 6 cm.

DIAMETER  1 mm.

LOCATION  The digital artery can be found on the ulnar and radial aspects of the finger between Grayson’s and Cleland’s ligaments and is dorsal to the digital nerve. The superficial arch is formed primarily by the ulnar artery and completed by the superficial palmar branch of the radial artery. In approximately 80% of hands, this arch is complete, whereas in 20%, there is no communication between the ulnar artery and the superficial branch of the radial artery. Classically the superficial arch or anastomosis between the radial and ulnar arteries is formed by the superficial volar branch of the radial artery (the smaller of the two vessels) and the much larger ulnar artery. The hands with a complete arch in this classic arrangement are seen 50% of the time; in the remaining half, the entire superficial arch is formed by the ulnar artery, with no contribution from the radial artery. The arch lies anterior (superficial) to the branches of the median nerve. Its branches include a palmar digital artery to the ulnar side of the small finger and three common palmar digital arteries running to the three web spaces between the fingers. As they course distally, they become dorsal through the median and ulnar sensory nerve branches. In the web spaces, they divide into palmar digital arteries for adjacent sides of the fingers. The palmar digital artery to the radial side of the index finger is a branch to the radial artery. Variations in this arrangement can occur. The palmar digital arteries represent the major blood supply to the fingers and form the basis for numerous homodigital flaps. They run dorsal and deep to the digital nerves and give off three dorsal branches that continue into the dorsum of the finger and anastomose with branches from the contralateral side. These dorsal branches represent the major source of blood supply to the dorsum of the fingers, and finally, at the level of the distal phalanx, each vessel ends in three to four anastomotic branches that join branches from the contralateral side of the fingertip and dorsum.

Minor Pedicle  Includes small perforators from the digital artery, which can be seen along the length of the digital artery

REGIONAL SOURCE  Digital artery.

LENGTH  5 to 10 mm.

DIAMETER  0.2 to 0.3 mm.

LOCATION  Extending in a volar direction into the pulp of the fingers.
Venous Anatomy

Venous drainage is through venae comitantes accompanying each digital artery, as well as venous plexus within the subcutaneous tissue of the flap.

Nerve Supply

Sensory  
Ipsilateral digital nerve is incorporated within the flap.

**Vascular Anatomy of the Homodigital Neurovascular (Littler) Island Flap**

**Fig. 9C-2**

**Dominant pedicle:** Digital artery (D)

n, Digital nerve
**FLAP HARVEST**

**Design and Markings**
A midlateral or zigzag incision is carried dorsal to the neurovascular bundle to incorporate the neurovascular bundle. Dissection is continued under the flap and over the periosteum and flexor tendon sheath. An oblique volar incision is then made spanning from the base of the distal tip amputation to the apex, which is found either at the proximal interphalangeal (PIP) joint, or more proximally at the proximal digital flexion crease, depending on how much advancement is required. Smaller triangular flap designs tend to atrophy and contract over time, so larger flaps are favored to minimize any risks of contracture and flap atrophy. To minimize postoperative flexion contractures, the oblique volar incision should be made using small Brunner zigzag incisions or using modified stepladder incisions, as described by Evans and Martin.

**Patient Positioning**
The patient is placed in the supine position, with the upper extremity abducted and in extension over a hand table. The hand is kept in supination.
GUIDE TO FLAP DISSECTION

The Brunner zigzag volar incision is made through subcutaneous tissue until herniating fat is observed. Dissection proceeds from distal to proximal and is carried down to the flexor tendon sheath. Planar dissection is superficial to this. Dissection is very similar to elevation of a Moberg flap, in which the flap is dissected off of the periosteum and the flexor tendon sheath. All fibrous septa are detached. A midlateral incision is then performed to delineate the dorsal extent of the flap. Dissection is carried dorsal to the neurovascular bundle, continuing under the flap and over the periosteum and flexor tendon sheath. The neurovascular bundle, which is included within the flap, is identified distally. It is carefully inspected throughout the flap elevation, which is carried from distal to proximal. The contralateral neurovascular bundle is identified and protected at all times, and the flap is detached from distal to proximal, freeing up and releasing all fibrous septa and soft tissue attachments. The dorsal branches of the digital artery are ligated as required for proper flap advancement.

Fig. 9C-4  (Adapted from Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, KY.)
If adequate advancement is achieved without ligating the dorsal branches, these are kept intact. Proper flap elevation as an island can yield more than 1 cm of advancement onto the distal finger.

If the flap is being used to resurface an adjacent digit or thumb, proximal dissection of the pedicle is carried down into the palm, taking care not to induce vasospasm. The surgeon must be careful to preserve a generous cuff of fibrofatty tissue around the pedicle throughout its length to minimize any risk of vasospasm or arterial ischemia.

**Fig. 9C-4**

- Flap design from radial side of ring finger to resurface volar thumb wound
- Tunneled flap inset with full-thickness skin graft to donor site
FLAP VARIANT

Modified Oblique Triangular Neurovascular Island Flap (Evans and Martin Stepladder Advancement Island Flap)

This modification uses step-cut incisions instead of a longitudinal volar incision or Brunner zigzag incision to avoid potential flexion contractures and longitudinal scarring.

The first surface landmarks and flap designs are identical to those for the standard neurovascular island flap, with the exception that the flap is designed based on three triangles of increasing size to minimize the risk of flexion contracture postoperatively. The width of the flap is equal to half of the peripheral length of the amputated surface, and the apex is located at or just proximal to the PIP joint crease. The flap design incorporates three triangles of increasing size, the distalmost being the widest and just crossing the midline. The lateral arm of the flap is marked just dorsal to the neurovascular bundle and curves gently dorsally. Volar incisions are made first down through subcutaneous tissue, and lateral finger flaps are developed to provide better exposure of the vascular pedicle. The dorsal incision is then carried down to the periosteum with care to preserve all dorsal digital sensory branches. The flap is elevated just above the periosteum and the flexor tendon sheath, and all fibrous septa are detached to free up the flap. The flap is advanced by interdigitating each major triangle, and the donor site is closed in a V-Y fashion. If mobilization is inadequate, more proximal mobilization of the pedicle is performed.

Fig. 9C-5  Stepladder advancement island flap for fingertip closure. (Adapted from Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, KY.)
ARC OF ROTATION
The neurovascular island flap is typically used as an advancement island flap for distal tip coverage but can be rotated up to 180 degrees to cover defects on the thumb and adjacent digits as well as the palmar and dorsal aspects of the hand.

Fig. 9C-6

FLAP TRANSFER
For fingertip coverage, the flap is simply advanced into the defect without tension. When used to resurface the thumb, the flap is dissected proximally into the palm to the level of the proximal palmar crease and is then tunneled subcutaneously into the thumb. If there are any concerns about tunnel compression or pedicle twisting, the entire palm should be opened from the base of the donor site incision across the palm to the base of the thumb, permitting precise placement of the pedicle.

FLAP INSET
The flap is inset and can be advanced in excess of 1 cm. The donor site is closed in a V-Y fashion to provide better support for the flap. The flap is inset with minimal tension over the distal tip defect and with some excess above the eponychial fold to account for postoperative contracture.
DONOR SITE CLOSURE
Simple sutures are used for closure under minimal tension and care is taken to interdigitate the three triangles in the Evans and Martin modification. If this modification is not used, we tend to use simple, smaller, zigzag Brunner incisions, which interdigitate very easily without any measuring or requirements of the stepwise triangles. When the flap is used to resurface the thumb, the donor site will require full-thickness grafting with either glabrous skin from the instep of the foot or a full-thickness skin graft from the upper inner arm.

CLINICAL APPLICATIONS
This patient presented with a degloving injury of the radial side of the pulp of the right middle finger. Sensate reconstruction is critical in this area, since the finger is used in fine manipulations. A homodigital neurovascular island flap was planned.

Fig. 9C-7  A, Lateral distal tip defect involving the right long finger. B, Design and markings for a neurovascular island digital flap for stable coverage. C, Flap dissection and island solely on the radial neurovascular bundle. D, The flap could be advanced up to 1.5 cm following adequate neurovascular pedicle dissection. E and F, Stable coverage was obtained with final flap inset. The patient had instant identical two-point discrimination for tip pinch. (Case courtesy Michel Saint-Cyr, MD.)
This right-hand-dominant patient presented with traumatic amputation of the distal phalanx. A homodigital neurovascular island flap was designed.

Fig. 9C-8  A and B, This 18-year-old male patient had an avulsion crush injury to the right long finger with an exposed distal phalanx and inadequate coverage. C-E, A neurovascular island flap was used to cover the distal tip and provide stable coverage. (Case courtesy Michel Saint-Cyr, MD.)
The ulnar aspects of the long or ring fingers are selected as the usual donor sites when the flap is required on another digit, because these areas are less critical for fine manipulations. The neurovascular island flap should include skin of the distal segment of the donor finger for two reasons: (1) to transfer the area of critical sensibility, and (2) to avoid a painful neuroma at the distal pulp donor site. Whereas the palmar margin of the flap corresponds to the palmar digital midline, the dorsal limit can extend up to the dorsal midline. Dorsal digital nerve branches should also be included in the flap if their corresponding dorsal skin territory is included in the flap design. Final dimensions of the flap, including its proximal extension, will be determined by the size of the recipient digit or thumb defect. In general, larger flaps are usually favored, because they encompass a larger sensory field and risk less injury and spasm to the pedicle during transfer.
Pearls and Pitfalls

- It is important not to skeletonize the neurovascular bundle and create spasm and problems with venous congestion. Leaving a generous cuff of fibrofatty tissue around the pedicle helps to minimize any risk of vasospasm or venous congestion.

- Straight oblique incisions incorporated in the flap design should be avoided to minimize any risk of flexion contracture. Incisions should not pass at 90 degrees across the proximal interphalangeal joint or any other joint in the hand at a 90-degree angle.

- The contralateral neurovascular bundle should be protected at all times so the remaining portion of the digit is not devascularized.

- It is easier to dissect from distal to proximal and from lateral to medial.

- The volar incision can be made first, and dissection is taken down to the flexor tendon sheath. The flap can be elevated off the flexor tendon sheath, enabling easy identification of the neurovascular bundle.

- The flap must be inset under minimal tension, and flexion of the PIP joint and metacarpophalangeal (MCP) joint should be performed as needed to minimize any tension on the closure. Flexion contracture can be avoided by progressive static extension splinting worn at night and during the day as tolerated. Patients should wear the splint nightly for up to 6 months to minimize any risk of flexion contracture.

EXPERT COMMENTARY

Michel Saint-Cyr

Indications

The homodigital neurovascular island flap is an extremely useful flap for digital tip coverage when local flaps are not suitable or available. This flap provides instant two-point discrimination once it is harvested and does not rely on peripheral neural ingrowth for two-point discrimination. It has all of the characteristics of the ideal tissue match, which includes color, texture, sensibility, and durability.

Recommendations

Technique

The volar oblique incision should be performed using small Brunner incisions, not a straight linear incision, to minimize any risk of future flexion contracture. I favor larger rather than smaller flaps and always try to have the skin paddle cover the entire neurovascular bundle so that it is not exposed and at risk for vasospasm. The skin paddle typically extends to either the PIP joint or more proximally in the vicinity of the proximal digital flexion crease, and the digital artery and nerve are dissected more proximally as needed to provide better flap advancement.

Once elevated, the flap is inset very loosely, and the tourniquet is released to confirm adequate blood flow into the flap. Care must be taken to preserve dorsal branches of the digital artery. If the flap is advanced sufficiently without having to divide the dorsal branches, then these are maintained. If not, these are cauterized, ensuring that the contralateral dorsal digital artery branch is preserved and maintains adequate blood supply to the dorsum.

Continued
Complications: Avoidance and Treatment
Flexion contractures are least likely to occur with a modified oblique triangular neuro-vascular island flap design or using small Brunner incisions instead of a standard straight oblique flap incision. Nevertheless, we place all of our patients in nighttime splints to avoid any flexion contracture, even when using Brunner zigzag incisions.

Take-Away Messages
When the flap is used to resurface the thumb, the patient should be warned that sensory retraining is required. This is more difficult to achieve in older patients, because sensory imprinting on the brain is so strongly established with advancing age.

Bibliography With Key Annotations
The authors reported the results of pulp reconstruction with a new heterodigital reverse-flow island flap. A dorsolateral flap from the middle phalanx, based on the digital artery is raised from the adjacent uninjured finger. The common digital artery, between the injured finger and the donor finger, is ligated and transected just before its bifurcation. The two converging branches of the digital arteries can be entirely mobilized as a continuous vascular pedicle for the flap. Thus the vascularization is now supplied by reverse flow through the proximal transverse digital palmar arch of the injured finger. To provide sensation the dorsal branch of the proper digital nerve from the donor finger can be included in the flap. Six reverse heterodigital island flaps were used in patients. In five patients the flap was used for pulp reconstruction and in one case for covering a dorsal digital defect. In one case mild venous congestion occurred. Good skin coverage with supple and well-vascularized skin was obtained in each patient. Static two-point discrimination over the flap was between 6 and 15 mm. This new procedure is indicated for extensive pulp defects in fingers in which reconstruction cannot be done using other flaps and as an alternative to microsurgical reconstruction.

The authors described a heterodigital neurovascular reverse-flow flap island flap for extensive pulp defects. A dorsolateral flap from the middle phalanx, based on the digital artery, is harvested from the adjacent uninjured finger. The common digital artery between the injured finger and the donor finger is ligated and transected just before its bifurcation. At this point the two converging branches of the digital arteries can be entirely mobilized as a continuous vascular pedicle for the flap. The vascularization is now supplied by reverse flow through the proximal transverse digital palmar arch of the injured finger; to provide sensation, the dorsal branch of the digital nerve from the donor finger must be included in the flap. This technique is indicated for large pulp defects with bone exposure of index and middle finger pulps, which are important for sensation.

Treatment of composite tissue loss in the finger pulp is often difficult. The authors presented their experience with the medial plantar artery perforator flap for repair of finger pulp defects and to restore fingertip sensation after traumatic injury. Free medial plantar artery perforator (MPAP) flaps were performed for digital pulp reconstruction in 10 patients (8 fingertips and 2 thumb tips). The flap’s blood supply was a perforator vessel of medial plantar artery, which was through the intermuscular septum between the abductor hallucis muscle and the flexor digitorum muscle. The recipient vessels were the digital artery and dorsal digital vein. The flap was not reinnervated during transfer procedures. The
donor sites were closed primarily in all cases. MPAP flaps are good in terms of general morbidity, cosmetic results, and durability. This flap is a valuable alternative method of repairing the glabrous finger pulp and tip defects.


Primary soft tissue coverage for large palmar defects of the fingers is a difficult problem for cases in which homodigital or heterodigital flaps cannot be used. The aim of this study was to explore the vascular and neural anatomy of the midpalmar area to assess the possibility of reverse island flaps from this area. In 24 cadaver hands perfused with a silicone compound, the arterial pattern of the superficial palmar arch and common palmar digital artery was examined. They detailed their findings and concluded that these flaps may be a useful reconstruction option for significant palmar soft tissue loss of the fingers.


Small to moderate-sized defects of the hand overlying joint surfaces, flexor tendons, Silastic implants, and tactile surfaces require full-thickness skin and subcutaneous tissue either for primary coverage or in anticipation of secondary reconstruction. Six difficult hand wounds were resurfaced with an arterialized island pedicle from the lateral surface of the nearby digit in lieu of multistage distant pedicle flaps. The Littler neurovascular island flap was modified to include only the digital artery and venae comitantes at its pedicle, preserving digital nerve intact in the donor digit. Microsurgical separation of the digital artery from the digital nerve minimizes the sensory loss of the donor digit. Cortical reeducation at the recipient site is unnecessary. The lengthy pedicle allows an arc of coverage over the palm, dorsum of the hand, and adjacent digits. Flap survival was 100%. Maximum flap size was 5.5 by 2.5 cm. Two-point discrimination of the donor defect averaged 4.5 mm. No significant donor morbidity was noted, with the exception of one case in which there was a mild degree of hypertrophic scarring across the volar aspect of the proximal interphalangeal joint. The one-stage procedure minimizes the number of hospitalizations and disability time. Its proximity to the site of injury, its versatility, and the relative speed with which it can be raised encourages its usage for primary coverage (two cases in this series). Preservation of near-normal two-point discrimination of the donor site allows either the radial or ulnar surface of the nearby digit to be used.


Fingertip or pulp resurfacing is a challenging reconstructive problem; the treatment varies widely. The authors reported the results of a dorsal island pedicle flap raised from an adjacent finger, including the bilateral dorsal digital nerves, for coverage of extensive soft tissue defect in the fingertip or pulp. They concluded that the dorsal island pedicle flap from an adjacent finger can be used for coverage of extensive fingertip or pulp defects, with maintenance of a normal-length digit and restoration of sensation on both the radial and ulnar sides of the finger pulp. They stated that sensation recovery in this series was superior to dorsal island pedicle flaps previously described in the literature, which did not include incorporation of both dorsal digital nerves.


Digital island flaps or cross-finger flaps have to be used for large defects; however, the digital artery is sacrificed when creating conventional homodigital island flaps, and two surgeries are required for the cross-finger flap. The authors described their experience in eight patients using an innervated reverse dorsal digital island flap that does not require sacrifice of the digital artery. The flap was supplied by the vascular network between the dorsal digital artery (the terminal branch of the dorsal metacarpal artery) and the dorsal branch of the digital artery. Venous drainage was through the cutaneous veins and the venous network associated with the dorsal arterial network. The flap was designed on either the dorsal proximal or the dorsal middle phalangeal region. The flap was harvested with the dorsal branch of the digital nerve (for the dorsal middle phalanx), the dorsal digital nerve (for the dorsal proximal
phalanx), or the superficial branch of the radial nerve (for the thumb), which was anastomosed to the distal end of the digital nerve. After flap transfer the donor site was covered with a full-thickness skin graft. Of the eight flaps, six survived completely, one had partial epithelial skin necrosis, and one showed central compression skin necrosis. Three flaps showed congestive changes from the first to the fifth day after surgery, which resolved by massage. All patients satisfactorily recovered sensation. The advantages of this flap are that the digital artery is not sacrificed, and only one surgery is needed. A disadvantage is the potential for venous congestion for the first 4 or 5 days after surgery.


All flaps described for the reconstruction of finger defects have limited indications and many disadvantages. The author successfully developed a reverse digital artery flap raised from the overall side and dorsal aspects of the proximal phalanx, excluding the digital nerve, for closure of fingertip and middle phalangeal defects; he called this the “reverse dorsolateral proximal phalangeal island flap.” The donor site defect was covered by another flap called the “dorsal metacarpal V-Y island flap.” The method was used for 12 complicated phalangeal defects in 11 patients. Flap sizes ranged from 2 by 1.5 cm to 3 by 2.5 cm. The flap was applied with versatile designs including distal interphalangeal or proximal interphalangeal anastomoses–based flaps; homodigital or heterodigital flaps from the injuries or adjacent finger, respectively; multiple flaps from the two distinct fingers in the same hand; and a sensate flap. The average follow-up time was 11.5 months. All reverse flaps and V-Y donor site flaps survived completely. Finger lengths and motions were satisfactory, with favorable aesthetic results in all cases. The mean value of static two-point discrimination was 9.3 mm. The author strongly advocates this new flap, as a single versatile flap, for repair of different-sized or complex phalangeal defects.


The heterodigital arterialized flap is ideal for nonsensory reconstruction of sizable soft tissue defects in the proximal fingers, web spaces, and the hand. The inclusion of a dorsal vein augments the venous drainage of this digital island flap and avoids the problem of postoperative venous congestion, which is a common problem in digital island flaps. However, the presence of a dorsal vein pedicle inhibits flap mobility somewhat, and the reach of the flap is mainly limited to adjacent fingers. In situations that demand a transfer from a nonadjacent donor finger or when the reach from the adjacent donor finger is inadequate, the dorsal vein pedicle can be temporarily divided and then anastomosed microsurgically after flap transfer is performed. This enables the reach of the flap to be extended up to two fingers from the donor finger. The authors performed this “partially free” heterodigital arterIALIZED flap in 11 consecutive patients between 1991 and 2001. The average size of the defects was 4.4 by 2.3 cm. All of the flaps survived completely, with no evidence of postoperative flap congestion. Healing of all of the flaps was primary and did not result in any scarring. All of the donor fingers had “normal” two-point discrimination of 3 to 5 mm. All of the donor fingers retained excellent or good total active motion, as graded by the criteria of Strickland and Glogovac.


Deep defects of the hand and fingers with an unhealthy bed exposing denuded tendon, bone, joint, or neurovascular structures require flap coverage. However, the location and size of the defects often preclude the use of local flap coverage. Free flap coverage is often not desirable, because the recipient vessels may be unhealthy from surrounding infection or trauma. In such situations, a regional pedicled flap is preferable. A solution to this is the heterodigital arterIALIZED flap. This flap is supplied by the digital artery and a dorsal vein of the finger for venous drainage. Unlike the neurovascular island flap, the digital nerve is left in situ in the donor finger, thus avoiding many of the neurologic complications associated with the Littler flap. The digital artery island flap is centered on the midlateral line of the donor finger. It extends from the middorsal line to the midpalmar line. The maximal length of the flap is from the base of the finger to the distal interphalangeal joint. By preserving the pulp and the
digital nerve, a sensate pulp on the donor finger remains that reduces donor-finger morbidity and also preserves fingertip cosmesis. The authors detailed their results with 29 flaps. Ninety-seven percent of the donor fingers achieved excellent or good total active motion according to the criteria of Strickland and Glogovac. Pulp sensation in the donor fingers was normal in 28 of the 29 donor fingers. No cold intolerance of the donor finger or the adjacent finger was reported in this series.


Sixteen upper extremities from fresh cadavers were dissected to delineate the anatomy, vascular pattern, and reconstructive potential of the heterodigital island flap. Fifteen heterodigital island flaps were also performed between 1996 and 2004 in 15 patients (mean age 41.2 years) with a major trauma of the thumb. Flap and donor site skin quality, scar contractures, finger mobility expressed in terms of total active movement, sensibility evaluated by two-point discrimination and the Semmes-Weinstein monofilament tests, cold intolerance, double-sensibility phenomenon, and cosmetic results were assessed. All patients were reviewed over a postoperative follow-up period of 10 to 18 months. Good coverage with well-vascularized skin was obtained and donor-finger full-thickness skin grafting was successful in all cases. All flaps survived completely. Mild cold intolerance was seen in all donor fingers, but no flap had hyperesthesia 10 months postoperatively. Total active range of motion was rated as good or excellent in all patients for both the donor finger and the thumb. Sensation in the donor finger was reported as “slightly altered,” and the double-sensibility phenomenon was present in all patients.
ANATOMIC LANDMARKS

**Landmarks**
Encompasses the entire second toe. The superior limit is the mid second metacarpal; the distal limit is the end of the second toe.

**Size**
Entire second toe.

**Function**
Plantar flexion of distal foot for push-off during ambulation; the second toe is expendable.

**Composition**
Composite (second toe), fasciocutaneous (first web space).

**Flap Type**
Type A.

**Dominant Pedicle**
First dorsal metatarsal artery (FDMA).

**Minor Pedicles**
First plantar metatarsal artery; second plantar metatarsal artery.

**Nerve Supply**
*Sensory*: Medial dorsal cutaneous nerve, medial terminal branches of deep peroneal nerve, common digital nerve.
Section 9D

HAND

Second Toe Flap

CLINICAL APPLICATIONS

Regional Use
  Plantar surface of foot

Distant Use
  (Microvascular Transfer)
  Hand

Specialized Use
  Thumb
  Digits
ANATOMY OF THE SECOND TOE FLAP

Fig. 9D-1

**Dominant pedicle:** First dorsal metatarsal artery

**Minor pedicles:** First plantar metatarsal artery; second plantar metatarsal artery
ANATOMY

Landmarks
Encompasses the entire second toe. The superior limit is the mid second metacarpal; the distal limit is the end of the second toe.

Composition
Composite (second toe), fasciocutaneous (first web space).

Size
Entire second toe.

Function
Plantar flexion of distal foot for push-off during ambulation; the second toe is expendable.

Arterial Anatomy (Type A)

Dominant Pedicle  
*First dorsal metatarsal artery (FDMA)*

**Regional Source**  Dorsalis pedis artery.

**Length**  5 cm.

**Diameter**  1.5 mm.

**Location**  Immediately distal to the head of the first and second metatarsal bones, the dorsalis pedis artery bifurcates into the FDMA and a deep branch into the deep plantar arch. The first metatarsal artery immediately proximal to the web space divides into a pair of digital arteries, extending into adjacent sides of the great and second toe.

Variations in the Origin of the First Dorsal Metatarsal Artery

The following classification describes the anatomy and frequency of these variations.

**Type A (Superficial) (49%)** The FDMA takes origin directly from the dorsalis pedis or from the superficial part of the deep perforating branch. This vessel then courses distally in a superficial plane.

**Type B (40%)** The FDMA arises from the lower part of the deep communicating branch or from the deep plantar arch. It lies deep under or within the first interosseous muscle and courses distally and dorsally, eventually becoming superficial between the head of the first and second metatarsal.

**Type C (11%)** The FDMA is very narrow or totally absent. In these patients the blood supply of the great and second toe depends largely on the plantar metatarsal artery.

In type A and B patients, the FDMA is available for use as the dominant pedicle. However, it may be necessary to dissect the deep communicating branch of the dorsalis pedis artery and the first metatarsal space to locate the origin of the FDMA. Distal exposure of the artery may require dissection within the interosseous muscle. In type C and selected type B patients, a second toe transplant requires use of the first plantar metatarsal artery (FPMA). In reported series of second toe–to–hand transplants, the FPMA is selected as the dominant donor arterial pedicle in 20% to 30% of patients.

Minor Pedicle  
*First plantar metatarsal artery*

**Regional Source**  Deep plantar arch.

**Length**  6 cm.

**Diameter**  1 mm.

**Location**  The deep plantar arch is formed by the junction of the lateral plantar artery with the deep branch of the dorsalis pedis artery as it extends through the first interosseous space. From this arch the second plantar metatarsal artery courses to the first web space and bifurcates into plantar digital arteries, entering adjacent sides of the great and second toe.
ANATOMY OF THE SECOND TOE FLAP

**F**
Distribution of deep peroneal nerve to web space and dorsum of great and second toe

**G**
Relationship of superficial and deep peroneal nerves to flap territory

**H**
Distribution of medial plantar nerve to web space and plantar surface of great and second toe

**I**
Relationship of dorsal and plantar digital nerves to first interosseous space

Fig. 9D-1
**Minor Pedicle**  *Second plantar metatarsal artery*

**Regional Source**  Deep plantar arch.

**Length**  6 cm.

**Diameter**  1 mm.

**Location**  At the level of the second web space, the second plantar metatarsal divides into digital arteries, entering adjacent sides of the second and third toes.

**Venous Anatomy**

The venous drainage is primarily through dorsal subcutaneous veins that drain into the dorsal venous arch distally. The arch drains dorsomedially into the greater saphenous vein, whereas the lateral border of the foot drains dorsolaterally into the lesser saphenous vein.

**Nerve Supply**

**Sensory**  *Medial dorsal cutaneous nerve*: This sensory nerve, a branch of the superficial peroneal nerve, extends lateral to the dorsalis pedis artery and divides into a medial and lateral branch. The lateral branch supplies the adjacent sides of the second and third toes.

*Medial terminal branches of deep peroneal nerve*: The medial terminal branch of the deep peroneal nerve courses medial to the dorsal pedis artery along the dorsum of the foot. It divides into two dorsal digital nerves in the first interosseous space; these nerves enter the adjacent sides of the great and second toe.

*Common digital nerve*: Branches of the medial plantar nerve provide sensation to the plantar aspect of the second toe.
Vascular Anatomy of the Second Toe Flap

Fig. 9D-2

**Dominant pedicle:** First dorsal metatarsal artery (D)

**Minor pedicle:** First plantar metatarsal artery (m)

- a, Dorsalis pedis artery; e, extensor digitorum longus; f, flexor digitorum longus; n1, plantar digital nerve; n2, dorsal digital nerve; v, superficial vein
**FLAP HARVEST**

**Design and Markings**

The skin of the second toe and the medial aspect of the dorsum of the foot may be included as a neurosensory flap. The skin of the dorsum of the foot may be included with the second toe as a composite flap.

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Fig. 9D-3

**A**

Web space flap design

**B**

Composite flap design

**C**

Short-transfer flap design

**D**

Double-transfer (second and third toe) flap design
The second toe is examined for size and shape and compared with the great toe for suitability for transplantation to the thumb position. The complete or second toe is used for reconstruction of missing ulnar hand digits.

The medial first web space and dorsalis pedis flap territory measuring 10 by 8 cm may be included with the second toe transplant (see Section 14D). Generally, minimal foot skin is included with the second toe to ensure direct donor site closure. A dorsal triangular flap measuring 2.5 by 3 cm in a smaller plantar triangular flap based superiorly to the second metatarsophalangeal (MTP) joint is generally included with the second toe.

The first dorsal metatarsal artery, the dominant pedicle to the second toe, is located between the first and second metatarsal bones lateral to the tendon of the extensor hallucis longus. In approximately a fourth to a third of patients, the FPMA is the dominant pedicle to the great and second toes. This pedicle courses deep to the interosseous muscles between the first and second metatarsal bones.

A circumferential second toe incision is made that includes a dorsal and plantar triangular flap based at the level of the second MTP joint. The dorsal triangular flap incision continues as a dorsal longitudinal incision located between the first and second metatarsal bones. A short longitudinal plantar incision may extend superior to the triangular flap as required for exposure of plantar structures.

**Patient Positioning**
The patient is placed in the supine position with the lower donor extremity prepared to the midthigh to allow knee flexion and external hip rotation for exposure of the plantar surface of the foot during the plantar portion of the second toe flap elevation.

**GUIDE TO FLAP DISSECTION**
Before leg exsanguination with application of the midthigh tourniquet, a light temporary tourniquet is placed at the midcalf level to distend superficial veins. Branches of the saphenous vein into the first and second web space are identified and recorded with a marking pen for later identification after elevation of dorsal foot skin flaps.

The superficial peroneal nerve is identified in its course superficial to the extensor retinaculum. Branches to the second web space are identified and preserved. The deep peroneal nerve is identified as it crosses through the extensor retinaculum between the first and second metatarsal bone at the midmetatarsal level. Branches to the second medial toe are preserved. Immediately inferior to the extensor hallucis brevis, as its tendon crosses the midmetatarsal level, the dorsal metatarsal artery and associated venae comitantes are identified between the first and second metatarsal bones. The artery is located immediately lateral to the deep peroneal nerve.

The extensor digitorum longus tendon is exposed over the dorsum of the second MTP joint. Division of the transmetatarsal ligament allows identification of the common plantar digital nerve and its bifurcation into lateral great toe and medial second toe branches. The plantar metatarsal artery is identified proximal to the second MTP joint distal to the plantar aponeurosis. The vessel is either identified through a dorsal approach after division of the transmetatarsal ligament or through the plantar aspect of the initial incision. Division of the transmetatarsal ligament between the second and third toes allows identification of the second plantar digital nerve. The tendons of the flexor digitorum longus and brevis to the second toe are identified through the plantar incision.
Standard Flap (Second Toe to Hallux)
The circumferential incision around the second toe includes a triangular flap based on the second toe at the level of the second MTP joint. This incision connects with a dorsal longitudinal incision between the first and second metatarsal bones to the level of the cuneiform bone at the midtarsal region. Medial and lateral skin flaps are elevated, preserving second toe dorsal veins previously identified before tourniquet inflation. The superficial peroneal nerve is identified superficial to the dorsal extensor retinaculum, with branches to the first and second web spaces preserved.

Fig. 9D-4

\[ e, \text{Extensor hallucis longus tendon; } h, \text{extensor hallucis brevis; } v, \text{superficial draining vein (saphenous system)} \]
The extensor hallucis brevis tendon is identified as it crosses the proximal first metatarsal space. The extensor retinaculum is incised. The FDMA and deep peroneal nerve are identified between the first and second metatarsal bones. The deep communicating branch through the plantar arch is also identified and preserved. The FDMA and medial deep peroneal nerve branches are dissected into the first web space, where the bifurcation into the lateral great toe (dorsal digital pedicle) and medial second toe (dorsal digital pedicle) is identified. Nerve and arterial branches to the medial great toe are divided.

**Fig. 9D-4**

**Dominant pedicle:** First dorsal metatarsal artery (*D*)
e, Extensor hallucis longus tendon; h, extensor hallucis brevis; n, deep peroneal nerve; p, dorsalis pedis artery; v, superficial draining vein (saphenous system)
The transmetatarsal ligament between the great toe and second toe is identified and divided. Immediately proximal to the first and second MTP joints, the plantar metatarsal artery and digital nerve are identified. Both are dissected to the plantar aspect of the first web space, and the arterial and venous branches to the great toe are divided. The plantar digital nerve is split for a 1 to 2 cm length proximal to its bifurcation, at which point its nerve fibers to the second toe are divided, leaving the medial branches to the volar great toe intact.

**Fig. 9D-4**

**Dominant pedicle:** Dorsal metatarsal artery (D)
e, Extensor hallucis longus tendon; h, extensor hallucis brevis; p, dorsalis pedis artery;
v, superficial draining vein (saphenous system)
The transmetatarsal ligament between the second and third toes is divided. The second plantar digital nerve is identified proximal to the second MTP joint. The nerve and adjacent second metatarsal artery are dissected into the second web space. Starting at the level of the bifurcation, the second plantar digital nerve is split for 2 cm, at which point the nerve branches to the lateral second toe are divided. Fibers to the medial aspect of the third toe are left in continuity with the second plantar digital nerve. Arterial branches of the second metatarsal artery to the second toe are divided, because this artery will not be used to revascularize the second toe.

The extensor digitorum brevis tendon is divided at the MTP joint. A long extensor tendon is dissected proximally to the level of the cuneiform bone to provide adequate length for upper extremity repair.

The flexor digitorum longus and brevis tendons are identified through the plantar incision and dissected proximally to the MTP joint. The interosseous muscles are separated from their attachments to the distal second metatarsal bone.
**Fig. 9D-4**

**Dominant pedicle:** First dorsal metatarsal artery (D)

- e, Extensor digitorum longus tendon
- f, Flexor digitorum longus tendon
- n, Dorsal digital nerve
- p, Dorsalis pedis artery

Release of extensor digitorum longus and brevis tendons

Release of flexor digitorum longus and brevis tendons

Division of flexor tendon
If the MTP joint is to be included in the second toe transplant, a bone osteotomy is performed in the distal second metatarsal shaft. If this joint is not required, the joint is disarticulated, with excision of the capsule and associated collateral ligaments and volar plate. With the proximal bone divided, the previously identified FPMA may be dissected to its junction with the deep plantar arch and communicating branch to the dorsalis pedis—first dorsal metatarsal arterial system. Retraction or division of the head of the flexor hallucis brevis muscle may be necessary for adequate visualization of the course of the plantar metatarsal artery. If the FDMA is clearly the dominant pedicle to the second toe, the proximal dissection of the FPMA is not required.

With division of the second distal metatarsal bone, it is now possible to expose the proximal tendon of the flexor digitorum longus and brevis to the second toe. These tendons are divided after adequate tendon length is achieved for proximal repair in the hand after second toe transplantation.

The tourniquet is now released, and circulation to the second toe and great toe is observed. If the dominant pedicle to the second toe cannot be identified with certainty, microclips are temporarily applied to the first dorsal and first plantar metatarsal arteries consecutively to observe second toe circulation. The minor pedicle is ligated proximally or is clipped, and a second arterial anastomosis is performed later, if required. After adequate perfusion is established, the toe is ready for transplantation to the hand position. At this point the second toe long extensor tendon and vascular pedicles are divided, and the second toe is transferred to the operative field of the hand dissection.
**Hand • 9D: Second Toe Flap**

**Fig. 9D-4**

**Dominant pedicle:** First dorsal metatarsal artery (D)

**Minor pedicle:** First plantar metatarsal artery (m)

e, Extensor digitorum longus tendon; f, flexor digitorum longus tendon; n, deep peroneal nerve; n₁, plantar digital nerve; n₂, dorsal digital nerve; p, dorsalis pedis artery; v, superficial draining vein (saphenous system)
Short Transfer
The initial incision is performed circumferentially with small distally based dorsal and plantar triangular flaps. The initial dissection begins on the lateral aspect of the first web space and the medial aspect of the second web space. The dorsal and ulnar digital arteries and nerves are identified. The superficial draining veins on the dorsum are preserved. The toe is either divided at the midproximal phalanx or at the proximal interphalangeal joint. The extensor digitorum brevis tendon is divided at the level of amputation. Proximal dissection of the long extensor tendon is performed, and the tendon is divided for an adequate length to reach suitable extensor tendons in the hand. Similarly, the flexor digitorum brevis tendon is divided short and the flexor digitorum longus tendon is dissected proximally to gain a greater length. The tourniquet is released. After perfusion of the second toe is confirmed, the finger is ready for transplantation to the hand recipient site. Multiple digital arterial and dorsal venous anastomoses will be performed with suitable receptor vessels in the amputated or absent digit.

![Dorsal digital artery and nerve](image1)
![Plantar digital artery and nerve](image2)

Short-transfer dissection

![Osteotomy technique: Proximal phalangeal level](image3)
![Osteotomy technique: MTP joint disarticulation](image4)

Fig. 9D-5
Joint Transplantation
The second MTP or proximal interphalangeal joint may be transplanted based on the dor-
sal metatarsal artery and associated venae comitantes and superficial draining veins. (The
vascularized second MTP joint is described in Section 14C.)
The dissection for the proximal interphalangeal joint is then performed as described
for a standard second toe transplant. However, a circumferential incision on the second toe
is not used. The dorsal web space incision is extended over the dorsum of the second toe.
The branch of the dorsal metatarsal artery to the second toe is dissected to the proximal
interphalangeal joint. Osteotomies are performed through the midproximal and middle
phalanges of the second toe. The long flexor and extensor tendons are retracted away from
the joint capsule, which is included in the transplant. Vascularized tendon and a dorsal skin
island may be included with the joint transplant, if necessary. Care is required to avoid disrup-
tion of the periosteal branch of the dorsal metatarsal artery to the proximal interphalangeal
joint capsule. The medial and lateral digital nerves are separated from the pedicle and are
not included in the joint transplant.

Fig. 9D-6

Proximal interphalangeal joint dissection

Osteotomy technique: Proximal and middle phalangeal levels

Fig. 9D-6
Double Transfer (Second and Third Toes)
A circumferential incision is made around both the second and third digits with a triangular flap located on both the dorsal and plantar skin proximal to the first and third web spaces. The technique is similar to the short transfer if the second toe alone is prepared for transplantation. In the dissection of the dorsalis pedis artery, its branch to the dorsal arch is identified and dissection proceeds laterally to expose the second dorsal metatarsal artery, which is preserved. If the first and second dorsal metatarsal arteries are inadequate or absent, the first and second plantar metatarsal arteries are dissected to the deep plantar arch. The arch will then be used as the donor artery for the paired digital transplantation. The extensor and flexor tendons for both second and third toes are identified and included with the transplanted double digits.

Fig. 9D-7

b, First dorsal metatarsal artery branch to great toe; d, plantar digital artery; e, extensor digitorum longus tendon; f, flexor digitorum longus tendon; h, extensor hallucis brevis; n1, deep peroneal nerve; n2, plantar digital nerve; p, dorsalis pedis artery; v, superficial draining vein (saphenous system)
The dorsal metatarsal artery is dissected proximally to the deep connecting branch to the deep plantar arch. This branch is divided and the proximal pedicle, which is now the dorsalis pedis artery, is dissected over the cuneiform bone. Further length is achieved by dividing the cruciform ligament, under which the artery courses from the distal leg. The extent of pedicle length is determined during preparation of the hand for the toe transplant. For this reason the dominant pedicle is not divided until a satisfactory receptor vessel is identified.

**FLAP VARIANTS**

- Segmental transposition
- Vascularized bone
- Sensory flap

**Segmental Transposition**
A portion of the web space or plantar aspect of the foot may be elevated as a neurosensory flap.

**Vascularized Bone**
Both the interphalangeal joint and the second metacarpophalangeal joint receive vascular communications from the FDMA and the second dorsal digital artery. Either the inner phalangeal joint or the second MTP joint may be elevated as vascularized bone with or without overlying dorsal skin.

**Sensory Flap**
The web space between the great and second toe may be elevated as a neurosensory flap based on the FDMA and associated venae comitantes and branches of the superficial and deep peroneal nerves.
ARC OF ROTATION

Standard Flap
Plantar skin may be elevated on the plantar surface of the second toe based on the second plantar metatarsal artery. This skin has a wide arc of rotation to cover defects on the plantar surface of the foot. The web space between the first and second toes may be elevated based on the FDMA as a neurosensory flap. If this flap is elevated to the dorsalis pedis artery and vein, it has a wide arc of rotation for coverage of defects on both the plantar and dorsal surfaces of the foot. Use of this tissue necessitates amputation of the digit or skin grafting of the resultant web space defect.
FLAP TRANSFER
The flap can be tunneled beneath a skin bridge if the tunnel is wide enough. Otherwise, it is preferable to incise the intervening skin bridge and skin graft the pedicle.

FLAP INSET
Second Toe to Thumb
Bone
The distal metatarsal or proximal phalanx of the second toe is fixed to the corresponding recipient site either for thumb or lateral digital reconstruction. Osteosynthesis is accomplished using interosseous monofilament wire loops, longitudinal Kirschner wire, paired oblique Kirschner wires, bone peg, or a combination of the above. The advantage with the longitudinal Kirschner wire is pinning the proximal interphalangeal joint in full extension and avoiding hyperextension in the MTP joint. This will reduce the potential for excessive proximal interphalangeal joint flexion. If oblique Kirschner wires are used, a capsulodesis of the plantar plate may avoid hyperextension of the MTP joint.

Osteotomy technique: Metatarsal level

Osteosynthesis with longitudinal Kirschner wire and interosseous wire

Fig. 9D-9
Nerve Repair
Medial and lateral dorsal sensory nerves are repaired with dorsal terminal branches of the radial nerve. The medial and lateral plantar sensory nerves are repaired with a digital nerve to the transplanted thumb or finger. If these recipient nerves are unavailable, other recipient sensory nerves include the radial nerve, palmar cutaneous branch of the median nerve, and dorsal sensory branch of the ulnar nerve.

Fig. 9D-9

Fig. 9D-10

Neurorrhaphy: Dorsal digital sensory to radial sensory nerve

Neurorrhaphy: Plantar digital sensory to median digital nerve
**Vascular Repair**
Arterial anastomosis is performed between the FDMA or dorsalis pedis artery and a radial artery or princeps pollicis branch. A venous anastomosis is performed between the superficial draining vein and the cephalic or appropriate superficial dorsal veins in proximity to the toe transplant.

**Tendon Repair**
In toe to thumb transplants the long flexor tendon is approximated to the flexor pollicis longus or alternate flexor tendon if the flexor pollicis longus is unavailable or absent.

In toe to ulnar digit transplants the long flexor tendon is repaired to the profundus tendon of the missing digit or alternate flexor tendon as required. The long extensor tendon is repaired to the extensor pollicis longus of the hand or, if that is unavailable, to the extensor indicis proprius. For transplants to ulnar digit sites, the extensor tendon is used as a recipient tendon. Tension is adjusted to allow thumb or finger extension with passive wrist flexion and moderate flexion with passive wrist extension.
Closure
The skin is closed using the dorsal and volar triangular flaps interposed with skin flaps on the recipient hand. Skin grafts may be required to complete closure, particularly on the lateral and medial aspects of the transplanted toe.

Second and Third Toe Transplants (Double Digit)
The flap inset sequence is identical to the single digit, except that the receptor tendons and nerves for both digits must be located.

DONOR SITE CLOSURE
The distal head and shaft of the second metatarsal bone are resected if not transplanted with the toe. The stump of the transmetatarsal ligament of the great toe and medial third toe are approximated with sutures. The skin is closed directly. In a double-digit transplantation, the transmetatarsal ligaments are not approximated. Soft tissue and skin are closed directly. In web space flaps, skin grafting is necessary to close the donor site.

Fig. 9D-13

Second toe donor site defect

Second toe closure technique

Double-transfer closure technique
CLINICAL APPLICATIONS
This patient’s thumb was amputated at the base of the proximal phalanx. Reconstruction with a second toe transfer was planned.

Fig. 9D-14  A, The thumb had been amputated at the base of the proximal phalanx. B-D, The appearance and function of the thumb is seen 4 months after reconstruction with a second toe transfer. (Case courtesy Fu-Chan Wei, MD.)
In this patient, multiple fingers were amputated, and two second toe transplantations were planned for the index and middle finger.

**Fig. 9D-15**  A, The patient’s index, middle, and ring fingers were amputated at various levels. B, Both second toes were harvested for replantation. C, The function and appearance of the reconstructed hand are shown 6 months after surgery. D, The donor site is shown 3 years postoperatively. (Case courtesy Fu-Chan Wei, MD.)
This patient’s distal index finger was amputated. It was reconstructed with a distal second toe.

Fig. 9D-16  A, Distal index finger amputation. B, The distal second toe was harvested. C, Appearance of the reconstructed distal index finger 1 year after surgery. D and E, The function of the reconstructed index finger is shown. (Case courtesy Fu-Chan Wei, MD.)
Pearls and Pitfalls

- The variability of the FDMA must be considered in planning the flap.
- Identification of both dorsal and plantar metatarsal arteries is recommended during flap elevation. The two pedicles may be temporarily occluded in sequence to ascertain the dominant pedicle. In general, the dorsal system is preferred because of the location of the radial artery on the dorsal radial aspect of the hand.
- Use of a tourniquet during flap elevation is recommended. Before division of the vascular pedicle to the second toe, the tourniquet is released and the flap observed for 15 to 20 minutes to ensure that circulation is adequate.
- Length and positioning of the second toe are critical to function and appearance, particularly in thumb reconstruction. The average thumb length extends to the proximal interphalangeal joint of the index finger. Exact length measurements can be obtained from the contralateral thumb. The second toe is rotated for pulp contact with the index and little fingers on thumb abduction and opposition before osteosynthesis. In lateral digital reconstruction the rotational deformities are avoided at the time of osteosynthesis by appropriate alignment of the nail bed in comparison to adjacent digits.
- In a child, the proximal phalangeal epiphyses are preserved to ensure finger growth.
- For second toe to thumb transplantation, alternative recipient structures in the hand include the following: (1) use of the extensor indicis proprius if the extensor pollicis longus is unavailable, (2) use of the long or ring finger sublimis if the flexor pollicis longus is unavailable, and (3) use of the ulnar digital nerve of the long or ring finger if the volar digital nerves are unavailable.
- Repair of sensory nerve should be accomplished if possible before second toe revascularization. This allows optimal visualization of the nerve ends in a bloodless field.
- Appropriate balance between the extensor and flexor tendon repair is important. Initial repair of the extensor tendon is accomplished to allow thumb extension with 90-degree wrist flexion. The subsequent flexor pollicis longus tendon repair is adjusted to provide mild second toe interphalangeal and MTP flexion with passive wrist extension.

EXPERT COMMENTARY
Fu-Chan Wei

Indications
The toes are structurally analogous to the thumbs and fingers, and they are the best autologous “spare parts” for thumb and finger reconstruction. Toe-to-hand transplantation is indicated for thumb reconstruction to restore prehension. Such a transfer is also indicated for finger reconstruction to restore pinch or grip. Both thumb and finger reconstruction aim to sacrifice a toe in exchange for an increase in the functionality of the hand. However, in select patients, partial toe-to-hand transplantation may be desired for fingertip reconstruction. Although such reconstruction restores more form than function, it can still be very beneficial to patients, especially in cultures (such as Asian) where missing a visible body part carries a negative connotation.
Advantages and Limitations

The second toe flap has less associated donor site morbidity than the great toe flap. When designed properly, the donor site of the second toe flap can usually be closed primarily, with an inconspicuous scar hidden within the web space. The resulting scar is also designed to lie on the non-weight-bearing area of the plantar foot to prevent the problem of tender scar in the weight-bearing area. In addition, because the great toe is largely responsible for the push-off phase of gait, sacrificing the second toe instead of the great toe ensures minimal disruption to the gait function.

Despite its many advantages over the great toe flap, the second toe flap does have its disadvantages. Using the second toe for thumb reconstruction will result in a less natural-appearing construct because of its smaller size and claw appearance. However, sometimes using the great toe for thumb reconstruction will result in a construct that appears too large. For the most natural-appearing thumb reconstruction, the trimmed great toe offers the best size match. Moreover, the second toe flap is limited to reconstruction of up to two digits, even if both second toes are harvested. For reconstruction of the metacarpal hand with finger amputation proximal to the web space, it becomes necessary to use a combined second and third, or third and fourth, toe flap.

Anatomic Considerations

As mentioned in the chapter, either the FDMA or the DPMA may be the dominant pedicle for the second toe flap. Its regional anatomy and variation may be confusing and challenging for surgeons unfamiliar with the flap. To avoid this problem, the technique of retrograde dissection is recommended.

Recommendations

Technique

Dissection of the vascular pedicle begins at the web space. The proper digital artery at the tibial side is identified and traced proximally to the region of the transmetatarsal ligament. At this location, the FDMA is located dorsal and the FPMA plantar to the transmetatarsal ligament. With this technique of retrograde dissection of the pedicle, no preoperative angiography is necessary.

Personal Experience and Insights

If the FPMA is the dominant pedicle, rather than perform extensive dissection through the interosseous muscles in the plantar foot to obtain more pedicle length, sometimes it is preferable to use a vein graft. Attempts to dissect extensively through the interosseous muscles may cause significant donor site morbidity.

For digit reconstruction, the triangular flap at the base of the harvested second toe should be carefully thinned and defatted to achieve a more aesthetic appearance and contour after the transfer. Excessive flap thickness will create a sharp transition at the junction of the hand and the transferred toe, making the transferred toe appear “stuck on.”

Reconstruction of a distal finger amputation (distal to the insertion of the flexor digitorum sublimus) with a second toe or another lesser toe is most rewarding for both function and cosmesis. It does not require complicated postoperative rehabilitation, and sensory recovery is fast. For fingertip reconstruction, the precise length of the second toe required for the reconstruction should be determined before surgery, so that the level of the second toe osteotomy can be planned and performed in one attempt. Once the distal
portion of the second toe has been detached from the foot, performing an additional osteotomy to shorten the bone becomes more technically challenging and dangerous, with a risk of injuring the vascular pedicle. The contralateral digit serves as a good guide when determining the required toe length for fingertip reconstruction.

**Complications: Avoidance and Treatment**

Vasospasm can be problematic. Every measure should be taken to prevent or minimize the risk of vasospasm, such as adequate patient hydration, adequate postoperative pain control, use of a regional block, and sympathectomy by skeletonization of the vascular pedicle.

**Take-Away Messages**

For the best thumb reconstruction, the second toe should not be proposed as the first choice. However, when it is used, the length of the reconstructed thumb and the amount of pulp rotation required to achieve good opposition should be precisely decided, or should be slightly shorter rather than longer.

When raising the flap, a retrograde dissection technique should be used to clearly delineate the dominant vascular pedicle and save the minor vascular pedicle as the spare (“lifeboat”) vessel. The vascular pedicle should be gently skeletonized. This not only minimizes the chance of the vascular pedicle kinking or getting caught in the subcutaneous tunnel, but also provides the sympathectomy effect to minimize vasospasm. Furthermore, attention should be paid in designing the incision on the plantar foot to avoid placing a scar on the weight-bearing surfaces of the plantar foot.

**Bibliography With Key Annotations**


The difficulties of treating crush avulsion hand injuries with amputation of multiple digits are well known. The authors presented an alternative to the two-stage replantation procedure. In a single-stage operation, they transplanted the second and third toes of the left foot, a sensory free flap from the left great toe, and a microvascular free transfer from the fourth toe to the left hand to treat a patient with a left-hand skin avulsion of the whole palm and P1 of the index, long, ring, and small fingers. The left index finger had a complete amputation at the P2 level, and the long, ring, and small fingers all had complete amputations at the P1 level. A 10 by 14 cm reversed radial forearm flap and a combination of full- and split-thickness skin grafts were used to treat the rest of the defect. The authors reported that the outcome was optimal and recommended this procedure in the emergency setting.

Jaminet P, Pfau M, Greulich M. Reconstruction of the second metacarpal bone with a free vascularized scapular bone flap combined with nonvascularized free osteocartilaginous grafts from both second toes: a case report. Microsurgery 31:146-149, 2011.


The authors treated 26 patients with metacarpophalangeal joint defects (22 had skin and soft tissue components) by transplanting the toe proximal interphalangeal joint with skin flaps. Twenty-three patients had mechanical injury (time from injury to operation 1 to 6 hours) and 3 had secondary injury caused by trauma (time from injury to operation 3 to 12 months). The size of the joint defects ranged from 2 by 1 cm to 4 by 2 cm. Twenty-one donor site toe amputations and 5 joint fusions
were performed. All transplanted joints and skin flaps survived, with union occurring 6 to 12 weeks postoperatively. Flexion in the joints ranged from 30 to 75 degrees (average 45 degrees). Based on the total active movement/total passive movement assessment criteria, 8 fingers were excellent, 13 good, 3 fair, 2 poor. Walking was not affected. The authors concluded that transferring the second toe proximal interphalangeal joint with skin flaps to reconstruct the metacarpophalangeal joint provides good functional recovery.


The authors treated 21 patients (44 fingers) with whole-hand destructive injuries or hand-degloving injuries by transferring pedis compound free flaps. Eleven patients had whole-hand skin-degloving injuries, and 10 had proximal palm injuries with dorsal or palmar skin and soft tissue defects. The defect was repaired by the thumbnail flap of dorsalis pedis flap and the second toenail flap of dorsalis pedis flap in 5 cases, the thumbnail flap of dorsalis pedis flap and the second toe with dorsalis pedis flap in 4 cases, and bilateral second toe with dorsalis pedis flap in 12 cases. Distal interphalangeal joint toe amputation was conducted in the thumbnail flap donor site, metatarsophalangeal joint toe amputation was performed in the second toenail flap donor site, and full-thickness skin grafting was conducted in the abdomen. Forty-three reconstructed fingers survived, and one index finger repaired by the second toenail flap was amputated. All wounds healed by first intention. The palmar and dorsal wounds showed no apparent swelling. The appearance of the fingers was satisfactory. Walking was apparently not affected. The authors concluded that this method is effective for recovering partial sensation and hand function after whole-hand or hand-degloving injuries.


The second toe plantar flap is a small neurocutaneous flap used to reconstruct fingertip defects. Twenty-seven reconstructions using this flap are reported in this article. Two types of flap are discussed. In the first type, the second toe plantar flap is combined with an onychocutaneous flap (12 cases). In the second type, the flap is transferred to distal digital defects or secondary defects of the palmar side of the digits after contracture release (15 cases). The authors concluded that this flap provides nearly acceptable functional and aesthetic results with minimal donor site morbidity and is appropriate for distal palmar defects and skin defects of the digits. Arterial insufficiency of the pedicle must be considered as a possible complication when planning this flap. Advantages and pitfalls were discussed.


Over the course of approximately 6 years, 929 partial second toe pulp free flaps were performed in 854 patients to preserve digital length, cover exposed bone, and replace skin over unstable fingertip scars. The two-point discrimination test was used to assess progress in 156 patients at 1 year or more postoperatively. The overall survival rate of the flap was 99.7%. Fifty-seven patients had two fingertip defects covered with bilateral second toe pulp flaps, and 9 had three defects covered with bilateral second toe pulp flaps and a third-toe pulp flap. Donor site complications occurred in 59 cases: 39 hematomas and 20 wound separations. No gait disturbance or pain at the donor site was observed. Static two-point discrimination averaged 8 mm (range 4 to 15 mm). Additional surgical procedures were required in 264 patients: 154 skin grafts at the recipient site and 110 flap revisions. This procedure has the benefits of shorter surgical time and less morbidity because of the shorter pedicle and smaller flap. In addition, similar pulp tissue is transferred from donor site to the finger. It is the authors’ first choice for covering fingertip wounds.


The objectives of treating mutilating hand injuries are to ensure the patient’s survival, limb survival, and ultimately limb function. Sound, safe principles must be followed. After patients are stabilized and cleared of other potentially life-threatening trauma, the mangled hand is irrigated and debrided—the
cornerstone of early treatment. The initial surgery includes skeletal stabilization, revascularization, and replantation or the transfer of spare parts to restore functions. Soft tissue is best replaced with regional flaps and free tissue transfers. Second- or third-look surgeries may be required. Tenolysis, joint mobilization, or toe transfers may be performed at a second procedure to restore dexterity and function to the healed hand.


The authors presented 7 cases (10 fingers) of completely degloved fingers treated with a combined great toe wrap-around flap and second toe medial flap free transfer, revascularized with nerve repair. The great toe wrap-around flap with dorsalis pedis skin covered the dorsal and palmarmost side of the finger, and the second toe medial flap covered the proximal palmar portion of the finger. Follow-up ranged from 34 to 76 months. Rehabilitation started 2 weeks postoperatively. All fingers had a satisfactory appearance. All flaps survived except one, which had distal phalangeal necrosis. Primary wound healing occurred in 9 of 10 recipient areas and in all skin grafted donor sites (one had delayed healing). There was no pain or swelling at the donor sites. Range of active motion was 60 to 80 degrees in the MCP joint and 40 to 70 degrees in the PIP joint. Two-point discrimination was 8 to 12 mm. All patients walked with no interference. The authors recommended this procedure for patients with degloving finger injuries with intact phalanges and tendons.


The authors described the harvesting technique, anatomic variations, and clinical applications of a compound flap from the great toe and vascularized joint from the second toe for thumb reconstruction. Anatomic variations were studied in five fresh cadavers. The first plantar metatarsal artery had a larger caliber in 40% of dissections, the first dorsal metatarsal artery was larger in 40%, and they had the same caliber in 20%. The Gilbert classification of first dorsal metatarsal artery was 40% class I and 60% class III. In addition, this flap was performed on five patients with traumatic thumb amputation at the level of the proximal metacarpal bone. Follow-up ranged from 11 to 24 months. Four patients had good functional opposition and motion of transferred joints, with good pinch and grip strength. There was one flap failure, and donor site morbidity was minimal. The authors concluded that this compound flap has several advantages. It provides two functional joints, is useful for thumbs amputated at the carpometacarpal joint level, and preserves growth potential in children by transferring vascularized epiphyses. Disadvantages include a technically challenging harvest and longer operative time.


Though the free second toe transfer is a popular procedure for reconstructing thumb and finger defects, the result is unattractive. To correct this problem in the thumb, the authors inlaid a composite tissue strip flap from the fibula of the great toe (with the fibular proper plantar digital artery as the pedicle), combined in some cases with the island dorsal index finger flap, with the second toe before the reconstruction. To reconstruct the fingers, they transferred a crescent double-winged dorsal metatarsal flap, connected with the second toe and combined with the partial metatarsal bone. The study group comprised 36 patients, and follow-up ranged from 6 months to 3 years. The appearance of the thumb and fingers was improved, with normal caliber and length. The authors considered this an ideal method for reconstructing the thumb and fingers.


The second toe is often used as an alternative to the great toe for thumb reconstruction, because function is good and donor site morbidity is reduced; however, cosmesis is poor. This article described a modified second toe transfer performed in six patients. To correct the narrow neck of the transferred second toe, the authors harvested a flap from the adjacent side of the great toe and inset it into the volar aspect of
the toe to provide bulk. To reduce the bulbous tip, they made skin excisions on each side of the tip. To make the nail appear longer, they excised the eponychium. Follow-up ranged from 6 to 36 months. All patients had good function and cosmesis. Part of the great toe flap was lost in one case. The mean two-point discrimination in the transferred toes was 10.1 mm, with protective sensation present in the flaps. The range of motion of the transferred toe was 14 to 38 degrees at the MCP joint, 16 to 55 degrees at the PIP joints, and 20 to 36 degrees in the DIP joints. The authors concluded that these techniques effectively reduce donor site morbidity and improve cosmesis in patients who have second toe-to-thumb transfer surgery.
ANATOMIC LANDMARKS

| Landmarks | Dorsal skin of the fingers over the proximal phalanx (FDMA/kite), and the dorsal skin of the hand overlying the metacarpals (DMA/Quaba). |
| Size | \(3 \times 5\) cm (FDMA/kite); \(3 \times 8\) cm (DMA/Quaba). |
| Composition | Fasciocutaneous. |
| Flap Type | Type A. |
| Dominant Pedicle | Dorsal metacarpal artery (DMA). |
| Minor Pedicle | Cutaneous perforators of the DMA. |
| Nerve Supply | Dorsal sensory branches of radial and ulnar nerves. |
Section 9E

HAND

Dorsal Metacarpal Artery Flap

CLINICAL APPLICATIONS

Regional Use
- Hand
- Thumb
- Digits

Specialized Use
- Microvascular transplantation

Contributions to this chapter by Michel Saint-Cyr, MD, and Guenter Germann, MD, PhD.
ANATOMY OF THE DORSAL METACARPAL ARTERY FLAP

Fig. 9E-1

Dominant pedicle: Dorsal metacarpal artery
Minor pedicle: Cutaneous perforators of dorsal metacarpal artery
ANATOMY

Landmarks  Dorsal skin of the fingers over the proximal phalanx between the midlateral lines and the dorsal intermetacarpal skin of the hand.

Composition  Fasciocutaneous.

Size  3 × 5 cm (FDMA/kite); 3 × 8 cm (DMA/Quaba).

Arterial Anatomy (Type III)

Dominant Pedicle  Dorsal metacarpal artery

Regional Source  Dorsal carpal arch.

Length  3 to 5 cm.

Diameter  0.5 to 1 mm.

Location  The dorsal carpal arch is formed from dorsal carpal arteries arising from the ulnar and radial arteries. The vessels anastomose across the dorsum of the distal carpal row to form a vascular arcade that gives rise to four dorsal metacarpal arteries. Each metacarpal vessel courses distally over the dorsal interosseous muscle bellies to supply the skin and subcutaneous tissues covering the dorsum of each finger and its adjacent dorsal web space. The first dorsal metacarpal artery (FDMA) tends to be a discrete terminal branch of the radial artery rather than arising directly from the dorsal carpal arch. The fifth dorsal metacarpal artery may also arise as a terminal branch of the ulnar artery.

From its origin, each vessel courses distally toward the web space and communicates through the interosseous space with the deep palmar arch. Proximal to the web space, each of the second, third, and fourth dorsal metacarpal arteries divides into two dorsal digital branches, one to each adjacent side of the index, middle, ring, and little fingers. The FDMA supplies the dorsum of the thumb and radial side of the index finger, and the fifth dorsal metatarsal artery supplies the ulnar side of the little finger. Traveling distally along each side of the finger, the vessels divide into terminal branches midway along the proximal phalanx. The vessels supply the dorsal skin of the finger as far as the proximal interphalangeal (PIP) joint. Distally, the dorsal skin is supplied by branches of the palmar digital arteries.

Minor Pedicle  Cutaneous perforators of the dorsal metacarpal artery

Regional Source  Dorsal metacarpal artery.

Location  The cutaneous perforators along the DMA are found within the proximal, middle, and distal thirds. The perforator that forms the basis of the DMA perforator flap is found 1 cm proximal to the metacarpal head, just distal to the junctura tendinum.

Venous Anatomy

There are two venae comitantes of 0.2 mm and 0.3 mm in diameter that follow each DMA and provide venous drainage for the reverse dorsal metacarpal artery flap. The venous valvae develop incompetently and will dilate after the reverse dorsal metacarpal artery is elevated and harvested. There are also communications found between both venae comitantes; this improves venous drainage of the flap. A rich venous network exists in the connective tissues surrounding the cutaneous perforator distally. The subcutaneous tissue and connective tissue harbor a venous network that can provide adequate venous return for a perforator-based DMA flap.

Nerve Supply

Sensory  The DMA flap, or Quaba flap if a cutaneous perforator is used, can be harvested with a dorsal sensory branch of either the radial nerve or ulnar nerve to create a sensate flap.
**Vascular Anatomy of the Dorsal Metacarpal Artery Flap**

**Fig. 9E-2**

**Dominant pedicle:** Dorsal metacarpal artery (D)

n, Digital nerve; v, superficial dorsal vein
FLAP HARVEST

Design and Markings
The flaps included in this chapter, the first dorsal metacarpal artery (FDMA) or “kite” flap, the reverse dorsal metacarpal artery (DMA) flap, and the reverse dorsal metacarpal artery perforator (Quaba) flap, are loosely referred to as DMA flaps, so it is important to be specific as to which variation based on the first dorsal metacarpal artery one is referring to. Rather than list any one as a variation, for this chapter we will simply list and refer to each flap, leaving it to each surgeon to determine which is to be considered the primary flap.

The FDMA (kite) flap design runs from the metacarpophalangeal (MCP) joint of the index finger proximally to the proximal interphalangeal (PIP) joint of the index finger distally, the radial and ulnar borders being the midlateral lines on either side of the digits. (Fig. 9E-3, A). The DMA and Quaba flaps have similar elliptical skin designs, with the longitudinal axis centered on the intermetacarpal space, spanning the level of the metacarpal heads to the distal wrist. The ulnar and radial borders of the skin paddle are determined by a pinch test and by the ability to close the donor site primarily (Fig. 9E-3, B). A handheld pencil Doppler probe can be used to identify the dorsal metacarpal artery, as well as the cutaneous perforator emanating from the DMA in between the metacarpal heads, which corresponds to the pivot point for both the DMA and Quaba flaps. The pivotal point of the flap is approximately 1.5 cm proximal to the leading edge of the web space.

Patient Positioning
The patient is placed in the supine position with the upper extremity abducted and placed on the hand table.
GUIDE TO FLAP DISSECTION

First Dorsal Metacarpal Artery (FDMA) or Kite Flap

Dissection always starts at the dorsum of the hand, incising the proximal portion of the flap and including one of the large subcutaneous veins. Leaving as much soft tissue envelope around the pedicle is recommended to avoid venous congestion. For a kite flap, one does not need to identify the pedicle. It is visualized through the thin layer of epimysium, and one can take the entire width of the visible surface of the epimysium to secure the pedicle. Dissection of the epimysium starts at the second metacarpal and is carried radially from there. After the pedicle is secured, the distal part of the skin island is incised and the flap is raised in the tissue plane above the paratenon, which has to be kept intact for perfect take of the full-thickness graft.

![FDMA/kite flap](image)

Fig. 9E-4
Flap designed over index proximal phalanx and MCP joint

Flap elevation and transfer to dorsal thumb defect

Neurovascular pedicle showing perivascular soft tissue cuff

Flap is inset into dorsal defect and donor site is covered with a full-thickness skin graft

Fig. 9E-4  (B through E from Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, KY.)
Reverse Dorsal Metacarpal Artery (DMA) Flap
For harvest of a reverse DMA flap, flap dissection starts from proximal to distal. A No. 15 blade is used to make an incision on either the ulnar or radial aspect of the proximal portion of the flap markings. Dissection is carried down through skin and subcutaneous tissue just above the paratenon of the extensor apparatus. The axis of the flap is in the midline between adjacent metacarpals, and the dissection plane of the skin paddle is located underneath the epimysium of the interosseous muscle. The DMA in the intermetacarpal space is ligated proximally and kept attached to the overlying skin paddle. The epimysium overlying the interosseous muscles is elevated with the flap to ensure protection of the DMA. The DMA itself often lies within or below the interosseous fascia; therefore harvesting the epimysium with the flap protects the pedicle. Dissection is continued from proximal to distal until the junctura tendonum is reached. The point proximal to the junctura tendonum can determine the pivot point if the arc of rotation is insufficient, and the junctura tendonum can be transected; then dissection can continue up to the communicating branch between the DMA and the palmar metacarpal artery. The pedicle should be surrounded by the portion of subcutaneous tissue and a superficial vein that can be included within the flap to preserve and potentially improve venous drainage, if required, with the addition of a venous anastomosis, as needed.

Fig. 9E-5

Reverse DMA flap
Reverse Metacarpal Artery Perforator Flap (Quaba Flap)
Quaba and Davison first described this flap in 1990. Their work followed that of Earley and Milner, who published their results in 1987. The term perforator flap was unknown at this time. Quaba designed a flap based on a perforating vessel in the web space that arborizes in the subdermal plexus of the dorsal skin.

The Quaba flap is a perforator version of the first dorsal metacarpal artery flap. This flap is an orthograde flow flap with a blood supply based on cutaneous perforators derived from the distal portion of the DMA. Four to eight perforators originate along the proximal, middle, and distal thirds of the DMA. A dominant cutaneous perforator lies 1 to 1.5 cm proximal to the midinterior metacarpal head region and corresponds to the pivot point of the DMA perforator flap. This flap was described by Quaba and is a perforator flap version of the DMA flap. This flap does not include the main trunk of the DMA, and its vascular supply is based solely on the cutaneous perforator emanating either directly from the DMA or from the communicating branch between the DMA and the palmar metacarpal artery. The perforator can be found just distal to the junctura tendinum, which allows it to have a longer arc of rotation because of its more distal placement.

Fig. 9E-6  A, CT angiogram showing the dorsal metacarpal arteries and their multiple interconnections along their course. B, Cadaver latex injection study demonstrating the dorsal metacarpal arteries and the interconnections at the metacarpal head, the basis for the Quaba flap.
Fig. 9E-6  C, Quaba flap arterial supply. D, Extended Quaba flap arterial supply. E, Latex injected cadaver showing dissected dorsal metacarpal artery flap. One can see the blood supply of either an anterograde or retrograde flap and the basis of a perforator based flap. F, Closeup of the interconnection of the volar and dorsal arterial systems providing the basis for a retrograde flap.
Flap dissection is essentially identical to the harvest of the DMA, except that the plane of dissection initially is between the subcutaneous tissue of the flap and the paratenon. At no point is the epimysium of the interosseous muscles violated. The flap is elevated from proximal to distal until the junctura tendinum is reached.

Distal avulsion injuries to tips of long and ring fingers

The flap’s cutaneous perforator can be found just distal to the junctura tendinum. The perforator and its venous connections within the subcutaneous tissue surrounding this perforator must not be skeletonized; this could lead to venous congestion and flap ischemia.
Once a cutaneous perforator has been identified, it can be confirmed with a handheld pencil Doppler probe. At this point, the more distal portion of the skin flap is elevated off the surrounding subcutaneous tissue, and subcutaneous tissue and fascia surrounding the perforator are freed up until adequate rotation can be achieved without any excessive twisting or tension on the perforator.

Extended Dorsal Metacarpal Artery Flap

The extended DMA flap was first described by Pelissier et al. The pivot point moves distally toward the distal border of the web space. The feeding vessel is no longer the palmar perforator, but the first dorsal branch of the proper digital artery.

The DMA is usually included in the flap design. During flap dissection it is imperative to preserve as much tissue as possible in the web space. The distal arterial feeding vessel does not necessarily have to be identified. There are many small arterial contributions to the rich vascular plexus in the web space. However, the major palmar perforator should be identified and isolated.

After the flap is completely raised, the palmar perforator is temporarily occluded with a microclamp, and the tourniquet is released. Perfect flap perfusion indicates sufficient arterial flow through the perforator from the PDA and the small tributaries to the plexus in the web space. The palmar perforator can then be clipped and transected. This maneuver shifts the pivot point distally so that the distal interphalangeal (DIP) and the palmar aspect of the pulp can be reached.
To increase the arc of rotation of the standard DMA flap, the communicating branch between the DMA and the palmar metacarpal artery or common palmar digital artery can be ligated to lengthen the flap’s pedicle and render the pivot point more distal.

By doing so, the flap’s blood supply is maintained by communication between the dorsal branches of the digital artery and the terminal branches of the dorsal and metacarpal artery through retrograde flow. The surgeon must not skeletonize any of the subcutaneous tissue in which the terminal branches of the DMA and dorsal branches of the digital arteries are found. A zigzag incision is continued to the distal skin paddle to dissect the subcutaneous pedicle, which is kept as wide as possible to maximize venous drainage and arterial supply to the flap. The skin flaps overlying the pedicle are elevated with skin and dermis only to preserve all of the subcutaneous tissue that contains the pedicle. This dissection provides additional length to the flap pedicle and will allow the FDMA flap to easily reach the PIP joint, and even the DIP joint. An Allen’s test must be performed to confirm the patency of either the ulnar or radial digital artery on which this flap can be based. When raising a Quaba flap or FDMA perforator flap based off a DMA cutaneous perforator at the inter-metacarpal head area, an extended flap can be performed as well.
Again, the direct cutaneous perforator to the skin flap, which is found at the intermetacarpal space and on which the Quaba flap is based, can be ligated to extend the reach of the Quaba flap. A rich subcutaneous tissue pedicle is kept intact from the flap and between the flap and the dorsal branches of the proper digital artery. The pivot point is then distal to the metacarpal heads and allows the flap to reach the DIP joint. Elevation of flaps of skin and dermis only, leaving all subcutaneous tissue intact overlying the pedicle, must be performed with care to ensure flap success and minimize the risk of venous congestion or ischemia.

COMPOSITE DORSAL METACARPAL ARTERY FLAPS

DMA flaps can also contain segments of tendon, bone, or nerve. Planning is the key to success.

First Dorsal Metacarpal Artery Flap With Extensor Tendon

Dorsal digital defects following trauma often require not only skin coverage or resurfacing but also extensor tendon reconstruction. Providing a vascularized extensor tendon in combination with well-vascularized tissue and skin coverage is beneficial to maximize function so that patients can progress quickly into a rehabilitation program. The second dorsal metacarpal artery (SDMA) can be harvested with a portion or all of the extensor indicis proprius (EIP) to provide vascularized extensor tendon reconstruction. There are multiple cutaneous perforators running along the DMA that vascularize the adjacent extensor tendons, and this forms a basis for a vascularized extensor tendon chimeric FDMA flap. A strip of EIP can be harvested with the FDMA based on small cutaneous perforators from the DMA. This flap can either be a traditional DMA flap or can be harvested as a DMA perforator flap.

Fig. 9E-8
Sensate Dorsal Metacarpal Artery Flap

In certain instances the dorsal branches of either the radial or ulnar nerve can be incorporated into the flap to provide sensate reconstruction. The sensory branch to the radial or ulnar nerve is then anastomosed to the dorsal branch of the digital nerve or the digital nerve proper itself, depending on how distal the flap can reach. For segmental bone loss resulting from a traumatic injury, a corticocancellous bone graft and vascularized bone flap can be harvested in combination with the FDMA flap because of the rich interconnection between the DMA and the interosseous muscle and metacarpals.

Fig. 9E-8

Fig. 9E-9  Origin and course of the first dorsal metacarpal artery and dorsal sensory branches of the radial nerve. (Adapted from Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, KY.)
ARC OF ROTATION
First Dorsal Metacarpal Artery Flap
With proximal dissection of up to 6 cm, the FDMA flap will comfortably reach the distal thumb.

Fig. 9E-10
Reverse Dorsal Metacarpal Artery Flap
The standard point of rotation for the dorsal metacarpal artery flap is the point just proximal to the junctura tendinum. If a further pivot point is required to allow further reach, the junctura tendinum can be sectioned and the new pivot point becomes the communicating branch between the DMA and the palmar metacarpal artery. This communicating branch is usually found in the mid intermetacarpal head region. The flap can be rotated within an upward rotation, typically ranging from 90 to 180 degrees. When pivoted proximal to the junctura tendinum, the flap will easily reach the dorsal aspect of the proximal phalanx. Sectioning the junctura tendinum and allowing a more distal pivot allows a greater arc of rotation, in which case the dorsal PIP joint can be covered.

Dorsal Metacarpal Artery Perforator Flap
The arc of rotation for the Quaba flap, or first dorsal metacarpal artery perforator flap, is located distal to the junctura tendinum where the main cutaneous perforators vascularized in the flap are found. The perforator is usually 1 cm proximal to the intermetacarpal head and just distal to the junctura tendinum, and the Quaba flap, or first dorsal metacarpal artery perforator flap, is based on this cutaneous perforator. This direct cutaneous perforator determines the pivot point of this flap. The flap will easily reach the dorsum of the proximal phalanx and dorsal aspect of the PIP joint, as well as the palmar aspect of both of these regions.
Extended Dorsal Metacarpal Artery Flap
When greater arc of rotation is required, such as to reach the DIP joint, the cutaneous perforator of the Quaba flap can be transected and ligated, as can the communicating branch between the DMA and the palmar metacarpal artery in a standard DMA flap. With either one of these maneuvers, the FDMA flap depends solely on retrograde flow from the dorsal branches of the digital artery communicating through subcutaneous terminal connections to the terminal branches of the DMA flap. The pivot point therefore becomes distal to the MCP joint and just within the proximal third of the proximal phalanx. This maneuver greatly enhances the arc of rotation and reach of the flap, which will now reach the dorsum of the DIP joint.

FLAP TRANSFER
The flap is transposed into its recipient bed. Subcutaneous tunneling is not usually used because of the risk of pedicle compression.

FLAP INSET
Once the flap is rotated, there should be no tethering on the proximal portion of the flap at its pivot point. The tourniquet should be released once the flap has been rotated 180 degrees to ensure that there is no kinking or twisting of the pedicle. The flap should be inset with a minimum number of sutures to avoid ischemia or compression, which can lead to venous congestion of the flap. Even the loose inset flaps remodel extremely well over their recipient site. Any skin redundancy or irregularities can be excised later, although this is rarely indicated. By extending the distal edge of the skin paddle 1.5 cm distal to the cutaneous perforator for a Quaba flap or the junctura tendinum for a standard DMA flap, the donor site can be closed primarily, with no tension on the skin. Simple permanent or absorbable sutures are used to inset the flap, again with minimal tension, making certain that there is no new traction on the pedicle or the flap itself.

DONOR SITE CLOSURE
The donor site can be closed primarily when the width is 2 to 3 cm. If the donor site cannot be closed primarily, a split-thickness or full-thickness skin graft can be harvested to cover the donor site. Care must be taken to always preserve the paratenon over the extensor tendons to provide an adequate recipient bed for skin grafting. Deep dermal sutures are used to close the dermal aspect of the donor site, followed by either a subcutaneous closure with Monocryl or simple sutures with either 5-0 nylon or chromic suture. Usually, skin on a skin flap measuring up to 3 cm wide and 6 to 10 cm long will allow primary closure.
CLINICAL APPLICATIONS
This 32-year-old man presented with a work-related soft tissue avulsion on the dorsal aspect of the proximal phalanx of his left middle finger. The wound was open and contaminated, and the extensor digiti communis (EDC) tendon was lacerated and exposed. The wound was thoroughly debrided and the tendon repaired. A second DMA perforator flap was used to cover the defect. The dorsal hand skin is expendable and provides an excellent flap donor site for reconstructing soft tissue defects in the digits.

Fig. 9E-12  A, The wound was open and contaminated, and located on the dorsal aspect of the proximal phalanx of the left middle finger. The EDC tendon was exposed. B, The wound was radically debrided outside the zone of injury. This allowed immediate flap coverage and helped minimize any risk of secondary infection from residual devitalized tissue, and contamination. Partial loss of the exposed EDC tendon was noted. C, The tendon was repaired, and the clean wound was ready for coverage. D, A second DMA flap was designed based on a cutaneous perforator located just proximal to the juncturae tendinum. It should not extend proximal to the dorsal wrist crease. This flap will easily cover the dorsal proximal phalanx and proximal interphalangeal joint. The pivot point was the perforator between the second and third metacarpal heads, located with a handheld Doppler probe. A skin pinch test was used to confirm primary donor site closure. E, The flap was inset with loose sutures and with no tension or pressure on the flap. Stable, well-vascularized wound coverage was achieved. This flap allowed early, active range of motion, which is especially important in a manual worker. (Case courtesy Michel Saint-Cyr, MD.)
This patient had unstable soft tissue coverage over the dorsal aspect of the left thumb proximal phalanx, resulting in pain and limited function. Well-vascularized tissue in the form of an FDMA (kite) flap provided stable coverage and a better extensor gliding surface for improved range of motion.

**Fig. 9E-13**  
A, The flap was designed over the index proximal phalanx and MCP joint.  
B, The flap was elevated and transferred to the dorsal thumb defect.  
C, Neurovascular pedicle showing perivascular soft tissue cuff.  
D, The flap was inset into the dorsal defect and the donor site was covered with a full-thickness skin graft. (From Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, KY.)
This patient had a defect on the palmar aspect of the index finger over the metacarpal head.

Fig. 9E-14  A, Closeup of the defect. B, A reverse FDMA flap (reverse kite flap) was designed. C, The flap was rotated into the defect and inset. D, The donor site was closed primarily. (Case courtesy Guenter Germann, MD, PhD.)
This patient had a distal palmar defect in the middle finger of the right hand after a contusion injury.

**Fig. 9E-15**  
A, Closeup of the defect.  
B, A typical cutaneous tail was designed. The DMA was marked after Doppler identification.  
C, Flap harvest was almost complete. The paratenon was left intact. All other tissues, including the interosseous muscle fascia, were included in the flap pedicle.  
D, The harvested flap is shown. The supplying perforating vessel from the common digital artery was identified in the web space (arrow).  
E, After the tourniquet was released, perfusion appeared to be excellent, with no signs of venous congestion.  
F, The flap was rotated to fit perfectly into the defect while excellent perfusion was maintained. (Case courtesy Guenter Germann, MD, PhD.)
This patient had dorsal defects in the middle and ring finger after a contact burn.

Fig. 9E-16  A, The defect in the ring finger could be skin grafted. The defect in the middle finger required flap reconstruction. B, An extended DMA flap with a cutaneous tail was designed. C, The perforator supplying the conventional DMA flap was clipped. The flap relied on the perforators from the proper digital artery supplying the vascular network in the web space. D, After the tourniquet was released, the flap had excellent perfusion. E, The flap was rotated into the defect. F, The cutaneous tail design allowed tension-free skin-skin closure. G, The flap is seen several days postoperatively with excellent healing. H, The skin graft to the ring finger showed complete take. I, The patient demonstrates active range of motion 10 days postoperatively. (Case courtesy Guenter Germann, MD, PhD.)
This patient sustained an injury from a dog leash.

Fig. 9E-17  A and B, Closeup views of the defect. C, The wound is shown after radical debridement. D, A long, extended DMA flap with a cutaneous tail was designed. The tourniquet was released. The arrow shows the pivot point in the distal web space.
Fig. 9E-17  
E, The flap was sutured in place. Because of the cutaneous tail design, no tunneling was required. F, The donor site was closed primarily. G and H, Healing was excellent 12 days postoperatively, with no signs of venous congestion or partial flap loss. (Case courtesy Guenter Germann, MD, PhD.)
This patient had a complex defect at the dorsum of the proximal phalanx of the index finger after a crush injury.

A DMA flap was used in this patient’s burned and grafted hand to cover an exposed PIP joint.

Fig. 9E-18  A, Closeup view of the defect. B and C, The defect was reconstructed with a DMA flap. Twelve weeks after surgery, contour was excellent. No debulking was required. (Case courtesy Guenter Germann, MD, PhD.)

Fig. 9E-19  A, A DMA flap was sutured over the exposed joint. B, The flap healed well. (Case courtesy Guenter Germann, MD, PhD.)
This patient had a burn injury over the PIP joint. It was reconstructed with a DMA flap.

A variation of a DMA flap was used in this patient to reconstruct a wound over the proximal phalanx.

Fig. 9E-20  A, Flap design. B, DMA from a grafted area. C, The donor site was reconstructed with a split-thickness skin graft. (Case courtesy Guenter Germann, MD, PhD.)

Fig. 9E-21  A, The skin of the dorsum of the hand appeared to be too thick to use for coverage of the proximal phalanx defect. Therefore a fascial DMA flap was designed. B, After rotation into the defect, the flap was covered with a split-thickness skin graft. (Case courtesy Guenter Germann, MD, PhD.)
Pearls and Pitfalls

- The skin territory should not extend over the dorsal proximal interphalangeal joint surface to prevent scar contracture and loss of finger flexion at the donor site.
- The first dorsal metacarpal flap may not consistently reach the volar surface of the distal phalanx of the thumb for resurfacing.
- The DMA is adherent to the interosseous muscle and deep to the dorsal sensory nerve. Care is taken to avoid interruption of the cutaneous branches of this pedicle to the proximal phalangeal dorsal skin island.
- The DMA flap (or its perforator variant, the Quaba flap) is extremely useful for coverage of dorsal defects involving the proximal phalanx of the PIP joint or even the DIP joint when the flap is used as an extended variant. The second dorsal metacarpal artery and third dorsal metacarpal artery flaps are extremely reliable flaps because of the constant communicating branch linking the DMA with the palmar metacarpal artery. The fourth and fifth dorsal metacarpal arteries do not always have this communicating branch but are reliable as a cutaneous perforator variant of the DMA flap. During initial dissection, subcutaneous veins are harvested within the flap to maximize venous drainage, and the proximal subcutaneous vein between the flap can be dissected and clipped to provide additional venous outflow if needed following transfer. Whether harvesting this flap as a reverse DMA flap or a Quaba flap (cutaneous perforator DMA perforator flap), the paratenon overlying the extensor tendon should be respected at all times in anticipation for a skin graft for donor site closure, if required.
- A rich cuff of fibrofatty tissue should be kept around the DMA flap, especially over the cutaneous perforator if the flap is raised as a DMA perforator flap. The pedicle should never be skeletonized to avoid injury to any of the venous connections found within the subcutaneous tissue. In many instances, the cutaneous perforator does not even need to be visualized. It can be confirmed with a pencil Doppler probe, but leaving as much subcutaneous tissue around the pedicle as possible will maximize venous drainage and arterial supply to the flap.
- When rotating the flap 180 degrees, the tourniquet should be released before final flap inset to confirm that there is good arterial inflow and no venous congestion to the flap. If there is any venous congestion, the flap should be rotated and any kinking or twisting of the pedicle should be avoided or eliminated. Subcutaneous tissue should be released around the pivot point and perforator as needed to provide tension-free rotation and flap inset. There should be no tension on the flap inset to avoid damage to the flap pedicle.
- Only a few tacking sutures are required to inset the flap. Insetting the flap with multiple sutures under tension should be avoided at all costs. The flap will remodel extremely well over time once the swelling has subsided and the flap has matured.
- When harvesting this flap as an extended DMA flap or extended Quaba flap, the surgeon must maintain a wide pedicle to maximize connections between the dorsal branches of the digital artery and the terminal branches of the DMA. Skeletonization should be avoided at all costs to maximize blood supply. The skin flaps overlying the pedicle should be elevated very thinly to preserve all of the subcutaneous tissue within the pedicle.
- Use the “cutaneous tail” to avoid a segment of solely subcutaneous pedicle, which may have to be skin grafted. This flap design facilitates tension-free skin-skin closure.
EXPERT COMMENTARY
Guenter Germann

Indications
DMA flaps are extremely versatile, not only in design, but also in clinical applicability. With the advent of alternative flaps for coverage of the distal dorsal part of the thumb, such as the Moschella flap or the Brunelli flap, the indication for the kite flap has shifted in our institution. If the previously mentioned flaps are not applicable, the kite flap is still our first choice for reconstructing dorsal thumb defects. However, restoration of sensibility has become a major indication over the years. A sensate kite flap provides immediate protective sensibility when the pulp is reconstructed. All alternative procedures require neural coaptation with a nonpredictable result. This is absolutely justified in younger patients with a high likelihood of reinnervation. In older patients, we recommend a sensate kite flap to restore sensibility. The advantages are:

- The kite flap does not have significant donor site morbidity, unlike the Littler flap.
- It is not necessary to dissect through the palm or split the common digital nerve to increase the arc of rotation.
- There is a similar “loss of discriminative power” after flap transfer.
- The incidence of the “dual location phenomenon” is low.
- Immediate protective sensation is provided.

In addition to applications in the thumb, the kite flap can be used to reconstruct defects of the entire dorsum of the hand because of its long pedicle and wide arc of rotation. It can be raised as a free flap for use in the hand or to reconstruct the nasal floor in total nasal reconstruction.

DMA flaps, as well as Quaba-type flaps, are predominantly used to reconstruct dorsal digital defects, web space defects, and palmar defects caused by trauma, or soft tissue deficits after the operation for Dupuytren’s contracture, burn scar release, or tenolysis.

The extended versions easily reach the palmar aspect and the dorsum of the DIP joint and are used to reconstruct long and complex digital defects. We find an extended DMA flap far superior to a combination of a “regular” DMA flap and a crossfinger flap in complex digital defects.

Anatomic Considerations
Flaps from the dorsum of the hand have proved most reliable for reconstructing defects of the digits or dorsum of the hand and for restoring sensibility in the thumb.

Anatomic dissections have shown that the dorsal metacarpal arteries usually run just underneath the epimysium of the dorsal interosseous muscles. Cutaneous perforators branch off the arteries to supply the overlying skin. This is predominantly important for second through fourth DMAs, where the flaps are centered over the arteries running in the intermetacarpal spaces.

Not much has been written about the direction of arterial flow in the DMAs. They arise from the dorsal carpal arch, which is formed from the dorsal carpal branches of the ulnar and radial arteries. Distal to the junctura tendinum, they communicate with the palmar vascular system through a major perforator that, in our experience, frequently comes directly from the common digital artery.

The incidence of the DMA is 100% for first and second DMAs, and it decreases slightly toward the ulnar border of the hand to approximately 90% for the fourth DMA.
The kite flap raised on the first DMA is significantly different in its vascular anatomy. Although the pedicle also runs below the epimysium of the interosseous muscle, the flap is not located on the dorsum of the hand, but on the proximal phalanx of the index finger. The artery can be safely traced with a pencil Doppler device to the proximal third of the proximal phalanx, and is then often not detectable.

**Personal Experience and Insights**

Based on experience with a considerable number of kite flaps and DMA flaps, we have modified our flap design. They are now designed only slightly larger than the defect so that they can be sutured in place with nearly the original tension on the skin. It is our experience that flaps that are too large tend more toward venous congestion.

The skin island design was also modified to avoid several pitfalls. With the kite flap, tunneling the flap into the defect was always burdened with the risk of compromising the delicate pedicle. With the “cutaneous tail design” published by our group in 2007, several goals can be achieved:

- Tunneling of flaps to the thumb can be safely performed in the soft first web space.
- Extending the defect proximally and reconstructing with the “tailed” kite flap allows tension-free skin-skin closure.
- Skin grafts to pedicles of either the kite flap or other DMA flaps are no longer necessary.
- The entire vascular pedicle is covered by the skin island. Subcutaneous pedicles described in the article can be avoided; therefore more small, nonidentifiable vascular connections to the skin island can be preserved.
- Long zigzag incisions can be avoided.

**Take-Away Messages**

- All variations of the DMA flap are useful for reconstructing defects in the hand and digits if some precautions are considered during planning and dissection.
- It is important to make the pedicle as wide as possible by taking a wide strip of epimysium.
- The paratenon has to be respected at all times.
- The skin island should be designed with a cutaneous tail to benefit from the advantages of this design.
- As much tissue as possible should be preserved in the web space to secure sufficient venous outflow and to facilitate a distally shifted pivot point.
- The flap should be designed only slightly larger than the defect so that it is sutured under minimal tension. In our experience, a flap that is too large has a higher tendency for venous congestion.
- The kite flap easily reaches the thumb pulp and can restore sensibility of the thumb.

**References**

Hand • 9E: Dorsal Metacarpal Artery Flap

Bibliography With Key Annotations


Skin graft–free web space reconstruction of syndactyly can be achieved in several ways. Previously, the dorsal metacarpal island flap based on a direct cutaneous branch of the dorsal metacarpal artery has been used as an island V-Y advancement for web defects. In this study, the authors raised the dorsal metacarpal artery flap as an island but used it as a transposition flap in a series of 19 web defects. Follow-up ranged from 1 to 5 years. Early results were good, with no recurrence or web creeping. The authors concluded that by employing the flap as a transposition flap, the skin territory proximal to the pedicle is used more effectively, and the result is more comfortable.


The authors reviewed a series of 18 cases of reverse axial adipofascial flaps performed in an outpatient setting. These flaps use subcutaneous tissue of the lateral digital and dorsal metacarpal or digital areas and are positioned on the arterial branches anastomosing the volar and dorsal arterial networks of the fingers. They provided coverage of wide and distal defects. Proximal phalangeal defects were covered with metacarpal flaps. Defects over the proximal interphalangeal joint, thumb, and fingers were covered with digital flaps. Dissection was easy, fast, and preserved the collateral nerve and artery of the finger. The flaps could be performed simultaneously with bone, joint, and tendon reconstruction. Patients were allowed to mobilize the hand as early as possible. Partial distal necrosis occurred in one case and partial loss of the overlying skin graft in two cases. These resolved spontaneously. Donor site morbidity was minimal.


The authors described a one-stage procedure in which a sensate first dorsal metacarpal artery flap is mobilized from the dorsum of the adjacent index finger and used as an island pedicle skin flap to close extensive pulp defects over the distal phalanx of the thumb in eight patients. All had bone, joint, or tendon exposure. The pedicle included the ulnar branch of the first dorsal metacarpal artery, the dorsal veins, and the cutaneous branch of the radial nerve. To overcome the anatomic variability of this very small artery, the authors included the radial shaft periosteum of the secondary metacarpal bone and the ulnar head fascia of the first interosseous muscle. All flaps survived completely.


The authors presented a novel approach to the difficult clinical problem of releasing first web space contracture. Their patient was a 25-year-old man with extensive contracture over the first web space after trauma. They released the contracted structures and covered the extensive skin defect with a dorsal transposition flap with an extension to the territory of the first dorsal metacarpal artery flap. The functional and cosmetic results were excellent, without recurrence of contracture.


The authors presented their experience using the modified first dorsal metacarpal artery (FDMA) flap, including both dorsal branches of the proper digital nerve (DBPDN) to repair thumb tip degloving injuries in 11 patients (11 thumbs). Four patients had bone loss of 1 to 3 mm. The soft tissue defects were 2.6 to 4.6 cm long and 1.8 to 2.2 cm wide. The flap size ranged from 2.7 by 2.2 cm to 4.8 by 2.1 cm. The pedicle length ranged from 6.8 to 7.5 cm. Neuorrhaphy between the DBPDN and the proper digital nerve was performed on both sides in all cases. Follow-up ranged from 26 to 47 months. All flaps survived completely. At the final follow-up, the mean of the static two-point
Discrimination was 5 mm and 6 mm on the radial and ulnar sides of the distal part of the flap, respectively. The mean range of motion of the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints of the donor fingers were 73 degrees, 101 degrees, and 70 degrees, respectively.


The authors presented two cases of complex, severe hand injuries treated with pollicization of the index metacarpal based on the first dorsal metacarpal artery and venae comitantes. In both patients, the radial side of the superficial palmar arch was destroyed, and there was complete loss of the thumb ray and amputation of the index through the base of the proximal phalanx. The authors successfully created an opposition post from vascularized index metacarpal bone, with free flap soft tissue reconstruction.


Despite the variable vascular anatomy of the dorsal aspect of the hand, the first and second dorsal metacarpal arteries (DMAs) are always present. Therefore the reliability of a metacarpal bone flap decreases from the second to the fifth metacarpal bone. The authors examined the metacarpal segmental vasculization and described six new vascularized bone flaps from the third and the fourth metacarpal bones pedicled on the second or the third DMA in an anterograde or retrograde flow mode. Based on their results, the radial and the ulnar side of the third metacarpal bone could be harvested, respectively, on the second and third DMAs. The radial side of the fourth metacarpal bone may also be a reliable vascularized bone donor site. Metacarpal and carpal bones or proximal phalanges may be repaired with the flaps based proximally or distally.


Thumb reconstruction is the most crucial aspect of effectively managing burned hands debilitated by contractures; however, flap options are limited. In this article, the authors used a neurovascular island first dorsal metacarpal artery flap in 14 patients with thumb deformities from contracture. The time from injury to reconstruction ranged from 5 months to 17 years. All treatments were successful, with satisfactory functional and cosmetic results. Donor site morbidity was minimal, with an acceptable scar on the dorsum of the index finger. Tendon gliding was adequate and without extension deficit. The authors concluded that the first dorsal metacarpal artery flap is a reliable option for deformities involving the thumb and/or adjacent thenar area. It provides acceptable sensation, elasticity, durability, and skin match.


Numerous methods are available for restoring the aesthetic appearance and function of the hand. In this review article the authors described recent advances in soft tissue reconstruction of the hand. Topics include skin grafts and skin substitutes, refinements in digital coverage, the expanding uses of dorsal metacarpal artery flaps, challenges to traditional concepts of forearm-based donor tissue, and improvements in free tissue transfer.


Dially based dorsal metacarpal artery (DMA) flaps have been described by Quaba, Earley, Milner, and others. Common indications are soft tissue defects of the dorsum of the proximal phalanx and decreased finger length. The flap had been modified for use as a pure fascial DMA flap, as dorsal grafts for burned hands, and to avoid tunneling and permit skin-skin defect closure. The authors provided an overview of the evolution and refinements of the DMA flaps performed in a single center. DMA flaps provide excellent coverage in one stage, with independent vascularization. Primary closure of the recipient site is possible without sacrificing relevant arteries, such as the proper digital artery. However, the technique is quite demanding and may result in hair growth and a visible scar on the exposed dorsal part of the hand.

In this retrospective study of dorsal metacarpal artery (DMA) flaps, the authors presented their experience with this flap in a single center. They performed 41 distally based DMA flaps: 29 distally based DMA flaps, nine extended distally based DMA flaps, and three distally based DMA fascial flaps. Thirty-four flaps had no complications, five had partial necrosis that was successfully treated with a split-thickness skin graft, and two were unsuccessful because of infections. The authors concluded that distally based second through fourth DMA flaps are reliable, but require adequate surgical experience.

They are suitable for reconstructing all defects, including burns. Defects of the entire finger can be covered by one of the many variations of this flap.


The authors performed extended reverse dorsal metacarpal artery (RDMA) flaps in 12 patients with defects of the long finger. Emphasis was placed on donor site morbidity. Active and passive total range of motion and pinch grip strength of the neighboring finger were evaluated and compared with the corresponding finger of the contralateral hand. The donor site was further evaluated for cosmetic appearance and pain. There was no statistically significant difference for active and passive total range of motion between the neighboring finger and the same finger on the other hand; however, there was a statistically significant difference for pinch grip. The patients’ subjective evaluation of pain scored a value of 1.25 (mean) on a visual analogue scale (0 = no pain, 10 = maximal imaginable pain) and the mean score for cosmetic appearance was 8 (0 = worst cosmetic result, 10 = best cosmetic result). The authors concluded that, compared with other flaps, the extended RDMA flap is a fast and secure single-stage procedure for covering defects on the long fingers and has low donor site morbidity.


Surgical treatment of extensive pulp (zone 4) defects of the thumb, with exposed tendon or bone, has included local, regional, and free flaps. Foucher and Braun first used an island flap carried on a neurovascular pedicle consisting of the first dorsal metacarpal artery (FDMA). The authors performed seven innervated FDMA island flaps for thumb reconstruction. Follow-up ranged from 4 to 29 months.

In six patients the dominant hand was injured. In a retrospective clinical study, the following criteria were evaluated: (1) cause of the defect, (2) time of reconstruction (primary versus delayed), (3) survival rate of flap, (4) sensory function (Semmes-Weinstein monofilaments, static two-point discrimination, pain, and cortical reorientation), (5) TAM measured with the Kapandji index, and (6) subjective patient satisfaction measured using the SF-36). Based on these data, the authors concluded that the FDMA flap has a constant anatomy and easy dissection, and provides good functional and aesthetic results. Donor site morbidity is low if a full-thickness skin graft is used. This flap is their first treatment of choice for defects of the proximal phalanx and proximal part of the distal phalanx of the thumb.


The authors described their experience using an innervated reverse dorsal digital island flap for fingertip reconstruction that does not sacrifice the digital artery and is performed in one stage. They performed reconstruction with this flap in eight patients. It was supplied by the vascular network between the dorsal digital artery (the terminal branch of the dorsal metacarpal artery) and the dorsal branch of the digital artery. Venous drainage was through the cutaneous veins and the venous network associated with the dorsal arterial network. The flap was designed on either the dorsal proximal or dorsal middle phalangeal region. It was harvested with the dorsal branch of the digital nerve (for the dorsal middle phalanx), the dorsal digital nerve (for the dorsal proximal phalanx), or the superficial branch of the radial nerve (for the thumb), which was anastomosed to the distal end of the digital nerve. The
donor site was covered with a full-thickness skin graft. Six flaps survived completely, one had partial epithelial skin necrosis, and one showed central compression skin necrosis. Sensation was satisfactory in all patients. Static two-point discrimination ranged from 3 to 5 mm, and the Semmes-Weinstein test results ranged from 0.036 to 0.745 g. The authors concluded that this flap is a good option for homodigital tip coverage. The digital artery is not sacrificed, and only one surgery is needed. A disadvantage is the potential for venous congestion for the first 4 to 5 days after surgery.


This study focused on the quality of sensibility from an innervated first dorsal metacarpal artery (FDMA) island flaps and donor site morbidity at the index finger. Twenty-five patients had an innervated FDMA island flap to restore sensibility of the thumb. They were divided into two groups: age 50 years or older and age 50 or younger. The mean patient age was 48.3 years. Follow-up was carried out at 3 years (mean). Static two-point discrimination was 10.9 in the older group and 10.8 mm in the younger patients. The average loss of two-point discrimination of the flap compared with that of the donor area was 2.7 mm in all patients. Complete cortical reorientation occurred in seven patients older than 50 years and in five patients younger than 50 years. Total loss of range of motion of all donor-finger joints was 14 degrees, compared with the contralateral index finger. Twenty-two patients were satisfied with the result. The authors concluded that there were no age-related differences in the surgical results with the innervated FDMA island flap, and donor site morbidity was negligible.


The authors evaluated the clinical efficacy of the reverse second and third dorsal metacarpal artery fasciocutaneous flaps for repairing distal- and middle-segment finger soft tissue defects in 14 patients. All defects had an exposed phalanx or tendon. Flaps ranged from 2 by 4.5 cm to 3 by 7 cm. Follow-up ranged from 6 to 40 months. Two-point discrimination was 5 to 9 mm, and good finger function was recovered. The donor site was directly sutured without dermoplasty. Pigmented linear surgical streaks appeared at the donor site. The authors concluded that these flaps are good options for repairing distal- and middle-segment finger soft tissue defects because of the convenient dissection, minimal trauma, sufficient use of the dorsal metacarpal artery, large harvested area of the flap, and a good dissection range.


The authors performed 28 reverse flaps based on the second dorsal metacarpal artery in 28 cases of degloved fingertip avulsions. The defects were located distal to the distal interphalangeal joints and were 0.8 to 2.2 cm long. Ten defects were in the index finger, 13 in the middle finger, and five in the ring finger. Twenty-four flaps were treated in an emergency surgery. Four surgeries were performed to treat skin necrosis. Twenty-five flaps survived completely, and three had epidermal necrosis at the distal end. Twenty-five cases were followed for 4 to 27 months. Cosmetic and functional results were satisfactory. Two-point discrimination was 6 to 9 mm.


The authors shared their experience using the second dorsal metacarpal artery flap from the middle finger in nine patients with extensive volar thumb defects. All thumbs were of normal length. In all patients, injury precluded use of the first dorsal metacarpal artery flap. Donor sites were covered with full-thickness skin grafts. All thumbs were immobilized postoperatively. Rehabilitation was subsequently performed. Follow-up ranged from 24 to 30 months. All flaps survived completely, without complication, and provided good coverage. All patients had full active range of motion in both the donor finger and the thumb. The mean Semmes-Weinstein sensitivity and two-point discrimination scores of the flap were 4.02 g and 8.4 mm, respectively. Mild cold intolerance was present in all thumbs.
The authors recommended this flap for volar thumb defects in thumbs of normal length. Although its pedicle length is limited, it is a reliable alternative for reconstructing extensive thumb-pulp defects in one stage, especially when the first dorsal metacarpal artery flap cannot be used.


Extensive traumatic defects at the level of the proximal phalanx of the thumb require challenging replantation and reconstruction procedures. The authors reported their experience using a bilobed second dorsal metacarpal artery-based island flap harvested from both the index and middle fingers to treat 15 patients with completely or incompletely amputated thumbs and extensive defects in the proximal phalanx. This flap was chosen for its ability to cover the large size of the defects. After flap transfer, anastomoses were performed between the veins of the distal part of the thumb and the flap. Thirteen thumbs survived, and two failed. All flaps survived completely. Follow-up ranged from 24 to 29 months. The mean active motion arcs of metacarpophalangeal and interphalangeal joints were 32 degrees (range 15 to 45 degrees) and 31 degrees (range 0 to 47 degrees), respectively. All patients had full active range of motion in both the metacarpophalangeal and the proximal interphalangeal joints of the donor index and middle fingers. The authors concluded that this flap is a reliable technique for thumb replantation in patients with extensive defects in the proximal phalanx when a single-digit dorsal metacarpal artery island flap is too small.
ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>Flap is designed over dorsal aspect of the middle phalanx from radial midaxis to ulnar midaxis. The pivot point is located at the digital midaxial level toward the affected digit.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>1 × 3 cm.</td>
</tr>
<tr>
<td>Composition</td>
<td>Skin, subcutaneous fat.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type A.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Dorsal digital artery.</td>
</tr>
<tr>
<td>Minor Pedicle</td>
<td>Digital perforators.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td>Dorsal branches of the digital nerves, which can be anastomosed to the recipient site digital nerve for sensation (rarely done).</td>
</tr>
</tbody>
</table>
Section 9F

HAND

Cross-Finger Flap

CLINICAL APPLICATIONS

Regional Use

Coverage of volar aspect of adjacent digits’ middle phalangeal area
Distal digital tip coverage
Volar oblique fingertip amputations with exposed bone or tendon

With contributions by Michel Saint-Cyr, MD.
ANATOMY OF THE CROSS-FINGER FLAP

A
Dorsal digital artery

Arterial anatomy

B
Dorsal digital nerve

Nerve supply to flap area; dorsal branches of digital nerve

C
Cleland’s ligament

Cross-sectional anatomy through middle phalanx showing Cleland’s ligament

Fig. 9F-1

Dominant pedicle: Dorsal digital artery
ANATOMY

Landmarks  Flap is designed over dorsal aspect of the middle phalanx from radial midaxis to ulnar midaxis. Pivot point is located at the digital midaxial level toward the affected digit.

Composition  Skin, subcutaneous fat.

Size  \( 1 \times 3 \text{ cm} \).

Arterial Anatomy (Type A)

Dominant Pedicle  *Dorsal digital artery*

The vascular supply of the dorsal skin distal to the distal portion of the proximal phalanx depends on perforating vessels from the digital arteries. These dorsal branches supply the flap. The perforating vessels course through Cleland’s ligament and anterior dorsal network, where they support a rich dermal and subdermal plexus. This supplies a laterally based cross-finger flap. There are two to four perforators over the proximal phalanx, midportion of the middle phalanx, and distal third of the middle phalanx.

**Regional Source**  Digital artery is derived from the common digital artery.

**Length**  Depends on the length of the finger and does not affect flap design or length. Although the flap is dependent initially on blood flow from the donor digital artery, this blood supply is completely separated at the time of flap division, because the flap develops a new blood supply from the recipient finger within 10 days after surgery.

**Diameter**  1 mm.

**Location**  Volar to the midaxial line of the finger.

Minor Pedicle  *Digital perforators passing dorsally around the finger*

**Regional Source**  Digital artery.

**Length**  Up to 1 cm.

**Diameter**  0.2 to 0.3 mm.

**Location**  Dorsal subcutaneous tissue.

Venous Anatomy

Dorsal subcutaneous veins accompany dorsal arterial branches. Small venules accompany the perforators arising from the digital artery and form the basis of venous drainage during the early phases after initial flap transfer.

Nerve Supply

Sensory  Dorsal branches of the digital nerves can be incorporated with the cross-finger flap to render it sensate. This nerve can be anastomosed to the terminal branches of the digital nerves. Sensory nerves are divided at the time of flap inset, unless a specific attempt has been made to anastomose a dorsal sensory nerve to the recipient digital nerve.
Vascular Anatomy of the Cross-Finger Flap

Fig. 9F-2  A, Cadaveric dissection of cross-finger flap. B, Closeup of digital bundle with perforating vessels supplying the flap. The proximal incision showing the feeding digital bundle is for demonstration purposes only.
FLAP HARVEST

Design and Markings

The cross-finger flap is designed with the base adjacent to the injured finger. This may be ulnar or radial, depending on the location of the injury. The proximal and distal extent of the flap is marked transversely. The markings are joined longitudinally just behind the midaxis of the dorsum of the finger opposite the injured digit, sparing the neurovascular bundle to the tip. This creates a three-sided rectangle, leaving the donor site pedicle intact on the side of the finger adjacent to the injured digit.

Incisions are made to encompass the whole surface of the middle phalanx as an aesthetic unit, with care to protect the paratenon and underlying extensor mechanism. The finger radial to the injured digit is usually used as a donor site, with the exception of the index finger, in which case a flap from the middle finger is used. To maximize distal reach during rotation, the flap can be designed to be oriented obliquely across the middle phalanx to allow a longer projection distally once it has rotated on its pedicle.
Patient Positioning
The patient is placed in the supine position with the hand abducted and extended on an armboard.

GUIDE TO FLAP DISSECTION
Dissection begins with an incision through the initial skin markings and is carried down through subcutaneous fat until a loose areolar tissue plane is encountered. Elevation of the flap at this point is relatively straightforward, as long as dissection is carried within this areolar tissue plane. The flap is then elevated off the paratenon; the extensor apparatus is protected at all times. All subcutaneous veins are clipped and ligated appropriately, and dissection is carried all the way up to Cleland’s ligament at the pivot point where the flap is facing a volar defect.

Division of Cleland’s ligament at the base of the flap may be necessary to increase pedicle length and reduce tension during flap inset. The flap is inset under minimal tension with permanent or nonpermanent sutures. Before flap inset, the donor site is covered with a full-thickness or partial-thickness skin graft. A full-thickness skin graft can be harvested from the groin to minimize any donor site scar on the volar aspect of the forearm, and this is sewn in with simple sutures of 5–0 chromic catgut, always ensuring that the paratenon is well protected. One strategy to minimize pedicle kinking and to augment the arc of rotation of the flap includes making small extension cuts to the base of the flap. Finally, the tourniquet is released. Some surgeons prefer to release the tourniquet after flap inset but before application of the recipient bed skin graft to secure hemostasis, thereby reducing the risk of hematoma formation beneath the graft, leading to graft loss.

The flap can be elevated as an oblique flap from proximal to midlateral. Once the flap is inset, a bulky soft dressing is used, as well as a Xeroform flap dressing so the skin paddle does not become dessicated. The hand and upper extremity are elevated for 10 to 14 days after excess flap tissue is placed over the donor site. Division and inset should be done no earlier than 2 to 3 weeks later.

Fig. 9F-4  A, Dissection begins distal to the flap’s pivot point, and the plane of dissection is kept just above the paratenon layer of the extensor tendon. B, Dissection continues until Cleland’s ligament is reached. Dorsal branches of the proper digital artery will be visible within the flap, as well as the subcutaneous veins. Cleland’s ligament can be transected as needed to increase flap mobilization. C, The flap is inset under minimal tension to the volar aspect of the adjacent index volar tip defect.
**FLAP VARIANTS**

- Reverse cross-finger flap
- Innervated cross-finger flap

**Reverse Cross-Finger Flap**

This is a useful flap for adjacent dorsal digital wound coverage including dorsal distal avulsions and exposure of the distal phalanx. A very thin skin flap overlying the subcutaneous tissue is carefully elevated at the subdermal plane, hinged contralaterally just above the midaxis line of the neurovascular bundle. Once the skin has been elevated and distally based on the contralateral side, a reverse subcutaneous flap is elevated based on the opposite side of the digit, adjacent to the injured digit. This adipofascial cross-finger flap can be used to rapidly restore venous drainage and dorsal coverage for digital reimplantation of avulsion injuries where the subcutaneous vein is used as a flow-through conduit after venous anastomosis. Division and inset is done 14 days after surgery, with trimming and readjustment of the flap at the donor site to maximize cosmesis. The arc of rotation of this flap is a little higher than the traditional cross-finger flap.

**Fig. 9F-4**  D, Cross-sectional anatomy of a standard flap and inset with relation to the neurovascular bundle and skin graft.

**Fig. 9F-5**  A, Design and B, elevation of a reverse cross-finger flap, with the plane of dissection just under the dermis to preserve the underlying subcutaneous tissue. C, The adipofascial flap is rotated similar to the standard cross-finger flap shown in A. This provides a vascularized bed for a full-thickness skin graft. The reverse flap, elevated at the dermis level, is returned to its bed, effectively forming a partially vascularized full-thickness graft itself.
Innervated Cross-Finger Flap
To maximize two-point discrimination in a distal tip reconstruction, optimal volar digital skin resurfacing should not only provide good cosmesis, but should also offer improved sensitivity to maximize function. A dorsal digital cutaneous nerve can be dissected proximal to the flap over the proximal phalanx. Once the flap has been transposed into its recipient bed, the donor nerve can be anastomosed to a side branch of the volar digital nerve in the recipient finger. This is rarely performed because of the technical demands of the procedure.

**ARC OF ROTATION**
The flap rotates like an open book from dorsal to volar.
FLAP TRANSFER
Flap transfer is performed in two stages:

- **Stage One:** The flap is transferred to the volar aspect of the recipient finger leaving its entire base attached to the donor digit, usually from its radial aspect. Care should be taken to ensure that the flap has been mobilized enough to allow for a tension-free transfer without any kinking of the skin bridge.

- **Stage Two:** Successful transfer depends entirely on the flap’s developing adequate vascular ingrowth from the recipient site. The longer and more secure the inset, the more rapidly and reliably this neovascularization takes place. It may be feasible to divide the flap pedicle as early as 10 days, but most surgeons will wait 2 to 3 weeks.

FLAP INSET
The skin bridge from the donor finger is simply divided longitudinally with a No. 15 blade and inset into the adjacent side of the recipient finger with interrupted monofilament sutures. The residual base of the flap on the donor finger is similarly trimmed and inset into the adjacent dorsal skin graft.

DONOR SITE CLOSURE
In a traditional cross-finger flap, closure is performed using a full-thickness or split-thickness graft to the dorsum of the donor finger. This is performed with a continuous 4-0 or 5-0 chromic catgut suture. If a dorsal compression dressing is desired, it should be secured with 5-0 nylon or silk tie-over sutures to enhance graft-to-bed apposition.
CLINICAL APPLICATIONS
This 18-year-old had a burn scar contracture of the volar aspect of the proximal phalanx, with limited extension of the metacarpophalangeal joint. After debridement of his contracture, stable resurfacing was provided with a cross-finger flap harvested from the adjacent long finger.

Fig. 9F-8  A, Appearance of volar aspect of the metacarpophalangeal joint with significant flexion contracture and limited range of motion. B, Resulting soft tissue deficit after contracture release and excision of scar tissue and exposure of neurovascular bundle. C, Cross-finger flap based on the dorsal aspect of the adjacent middle finger. Note oblique axis of the cross-finger flap to achieve a longer arc of rotation to cover the proximal ring finger volar soft tissue defect. D, The cross-finger flap was harvested from lateral (distal to the flap hinge point) to medial. The extensor tendon paratenon was carefully preserved to support a skin graft for donor site closure. The plane of dissection was kept within an avascular areolar tissue plane, which was easily defined.
Fig. 9F-8  E, The final aspect is seen after flap elevation with preservation of the extensor tendon paratenon, which next could be covered with either a split-thickness or full-thickness skin graft. F, Before insetting the cross-finger flap, a full-thickness skin graft was applied to the donor site for ease of insetting. The exposed pedicle was also skin grafted to prevent desiccation, and this was excised at the time of flap division-inset. G, Final flap inset with no tension. H and I, One week postoperatively, the patient was allowed to begin light active range of motion to minimize any joint stiffness. J, Three weeks postoperatively, the cross-finger flap was divided and excess tissue was trimmed or rearranged, as needed. (Case courtesy Michel Saint-Cyr, MD.)
This 16-year-old had a degloving injury of the volar aspect of the middle phalanx of the long finger.

Fig. 9F-9  A, The patient underwent flexor tendon reconstruction, pulley reconstruction, and ulnar and radial digital nerve grafting and was left with a soft tissue defect that was resurfaced with a cross-finger flap. B, A template of the defect was taken to better assess the cross-finger design and size required. C, The template size and orientation was placed on the donor site for accuracy of design. note: A larger cross-finger flap should always be harvested to prevent tension and account for soft tissue variables. The entire skin unit from the dorsal middle phalanx was harvested. D, The cross-finger flap elevation began distal to the pivot/hinge point of the flap, and dissection was kept above the paratenon. The extensor paratenon was kept moist during the procedure to prevent inadvertent desiccation. E, Before cross-finger flap inset, the donor site was skin grafted with a full-thickness skin graft harvested from the ipsilateral thigh. F and G, Final aspect of the donor site and recipient sites. H, Appearance of the cross-finger flap 3 months after division and inset, with good contour and color match. (Case courtesy Michel Saint-Cyr, MD.)
This 14-year-old girl presented with an avulsion injury to the right ring finger.

**Fig. 9F-10**  
**A,** The injury resulted in loss of soft tissue, partial loss of the eponychial fold, and an exposed distal interphalangeal joint.  
**B** and **C,** Reverse cross-finger flap and crescent dermal flap for soft tissue coverage and reconstruction of the eponychial fold.  
**D,** The skin flap was elevated above the subcutaneous tissue layer. The base of the raised skin flap is contralateral to the reverse cross-finger flap pivot/hinge point.  
**E,** The crescent flap was deepithelialized and the contralateral aspect of the cross-finger flap was incised.  
**F,** The reverse cross-finger flap was inset into the defect, and the dermal portion of the flap was used to reconstruct the eponychial fold.  
**G,** A split-thickness skin graft was used to cover the reverse cross-finger flap. (Case courtesy Michel Saint-Cyr, MD.)
This 55-year-old woman had a schwannoma of her left small finger. After resection, there was a significant soft tissue defect that required more than a skin graft for coverage and best cosmesis. A cross-finger flap was planned from the dorsum of the neighboring ring finger.

Fig. 9F-11  A, The defect and the elevated cross-finger flap are shown. The digital vessels have not been exposed in the base. B, The flap was inset without tension into the defect in the small finger. C, Volar view. D, The dorsum and exposed flap were skin grafted with a full-thickness skin graft from the groin, seen here healing well at 2 weeks postoperatively. E, Division and inset, performed 2 weeks after initial placement. F, The result is seen 4 months postoperatively, with good cosmesis and function. (Case supplied by MRZ.)
This patient presented for flap coverage after radical debridement of an infected perforating injury.

Fig. 9F-12  A, The injury is shown with flexor tendons exposed. B, Design of a conventional cross-finger flap on the dorsum of the ring finger. C, The flap was raised under loupe magnification; a tourniquet was used. The paratenon of the extensor tendon was preserved to guarantee graft take for donor site reconstruction. D, The flap fit perfectly into the defect and was temporarily fixated with stay sutures. E, The flap was sutured in. After release of the tourniquet, the flap showed excellent perfusion. (Case courtesy Guenter Germann, MD, PhD.)
A cross-finger flap was used in this patient after a penetrating injury. The defect is shown following tendon repair and a secondary wound infection.

**Fig. 9F-13**  
A, The situation is seen following debridement with exposed flexor tendon.  
B, Design of the cross-finger flap over the middle phalanx of the middle finger.  
C, The flap had excellent perfusion at the end of the operation.  
D, The patient was able to perform active motion with the flap still attached 10 days postoperatively.  
E, Fourteen days postoperatively, the flap is well healed. (Case courtesy Guenter Germann, MD, PhD.)
This case is an example of long-term aesthetic and functional results.

Fig. 9F-14  A and B, The patient's hand is seen after division of the flap. Note the ugly appearance of the donor site after reconstruction with a thick split-thickness skin graft and the granulation tissue at the site of flap division. C, Aesthetic appearance of the recipient site at the palmar aspect of the middle phalanx of the index finger. D, Function of the reconstructed index finger and the middle finger 12 months postoperatively. E, The aesthetic appearance of the donor site is excellent at the patient's 12-month follow-up. (Case courtesy Guenter Germann, MD, PhD.)
Pearls and Pitfalls

- Never design a cross-finger flap on the volar surface of a digit. Use only a standard or reverse flap from the dorsum, which can tolerate the loss and take a graft better.
- To maximize distal coverage, the flap can be designed obliquely, with the base of the flap placed distally and the proximal portion of the flap found proximally once the flap has been incorporated.
- When raising a reverse cross-finger flap, the surgeon should raise the overlying skin as an extremely thin cutaneous flap based on the contralateral side of the finger. The subdermal plexus should be preserved with the skin flap.
- There should be no tension on the flap inset to prevent wound dehiscence.
- The flap is immobilized without tension in a plaster cast or splint for 12 to 14 days. After division and inset, early active range of motion exercise should be started. Vigorous physical therapy is essential to prevent joint stiffness and flexion contractures.

EXPERT COMMENTARY

Michel Saint-Cyr

Advantages and Limitations
The cross-finger flap is a very robust and dependable flap. It is useful for coverage of the volar middle phalangeal area and the dorsal digital and distal tip. One of its major disadvantages is the need for 2 to 3 weeks of immobilization; this places patients at risk for joint stiffness and flexion contractures, particularly in those over 35 years of age.

Recommendations

Technique
The flap is elevated off the paratenon, and additional subcutaneous tissue can be harvested as needed to provide better bulk for volar tip coverage from the proximal and distal portions of the dorsal donor site. Also, harvesting the flap with the dorsal digital nerve branch can provide sensate fingertip reconstruction with neurorrhaphy of the dorsal digital branch incorporated in the cross-finger flap to a digital nerve stump of the reconstructed digit. The entire dorsal middle phalanx skin should be harvested to accommodate some adjustments and tearing in the flap inset.

An alternative is to design an oblique pattern of cross-finger flap to provide a pivot point, which provides more distal coverage. One key step is to skin graft the donor site before insetting the flap, which will make skin graft insetting much simpler.

My preferred donor site is the groin—the graft should be obtained from a non-hair-bearing skin donor site. The graft is sewn in with continuous catgut sutures. I prefer using a full-thickness skin graft. The flap is inset into the defect under minimal tension and with application of a petrolatum gauze dressing. The tourniquet is released before the dressing is applied to confirm adequate vascularity. For a reverse cross-finger flap, dorsal digital veins can be used as the vein graft for dorsal vein neurorrhaphy.
EXPERT COMMENTARY
Guenter Germann

Indications
Cross-finger flaps are robust and in their design modifications versatile. Main indications for the conventional cross-finger flap are palmar defects of the middle phalanx, over the proximal interphalangeal (PIP) joint, or the proximal phalanx. For a reversed cross-finger flap, the indication is soft tissue defects over the dorsum of the digits.

Anatomic Considerations
In our understanding, there is no dominant pedicle in the cross-finger flaps. The flaps are based on small perforators branching off the proper digital artery penetrating the Cleland ligament structures. This holds true for both modifications of the cross-finger principle.

Flap Design
The flaps are designed as rectangles, or slightly oblique, or in selected cases, even with a kite design. We have adopted the principle of selecting the most suitable finger as the donor site, which means that the rule that the radially located finger serves as the donor site is frequently not applied.

Recommendations

Technique
During dissection, we place the hand on a hand table and the patient in the supine position. Dissection is performed under tourniquet control. The tourniquet is released only after the flap has been inset and the skin graft for reconstruction of the donor site has been harvested. Good hemostasis is achieved before the skin graft is applied.

Preservation of the paratenon of the extensor mechanism is of utmost importance during dissection to guarantee graft take at the donor site. Subcutaneous veins are usually coagulated with bipolar cautery, since vessel clips are too bulky, as are ligatures. Dissection is easy and straightforward. The flap is mobilized to the digital midline, and in some cases beyond the midline after Cleland’s ligaments have been transected. The perforators are easily visible under loupe magnification, because we do not exsanguinate the extremity before the tourniquet is closed.

Fig. 9F-15  A, Typical indication for a cross-finger flap: volar defect with exposed flexor tendons.

Continued
of the proper digital nerve if a sensate flap is desired. Into the flap. In more proximal uses, the dorsal nerve branch can be coapted to the stump. Usually the flaps are insensate, and it is often not possible to include a dorsal nerve branch. Adhesions and eventual limited active range of motion. "Buddy tapping" allows early active exercise of the fingers (usually after 3 to 5 days), helping to avoid the patient will be painful and will force the patient to halt this activity. Buddy tapping through the pulp of the donor and recipient fingers. Any lateral movement of the fingers in under minimal tension. The flap can be protected by placing a thick "holding suture" in the subdermal plane toward the contralateral border of the donor digit (open book). All subcutaneous tissue, which forms a very delicate flap, is raised from the remote digital border above the paratenon toward the defect and is based on the perforators from the proper digital artery. The flap is then flipped over into the dorsal defect and fixed with some stay sutures. The thin skin flap is then used to cover the donor defect (closed book). We find that this delicate flap does not offer as much mechanical stability as the conventional cross-finger flap and has an arc of rotation that is slightly smaller than the conventional flap.2,3 Reverse Cross-Finger Flap This modification is raised in the “open book−closed book” technique and is used for dorsal defects. After a skin incision at the flap border adjacent to the defect, the skin is elevated in the subdermal plane toward the contralateral border of the donor digit (open book). All subcutaneous tissue, which forms a very delicate flap, is raised from the remote digital border above the paratenon toward the defect and is based on the perforators from the proper digital artery. The flap is then flipped over into the dorsal defect and fixed with some stay sutures. The thin skin flap is then used to cover the donor defect (closed book). We find that this delicate flap does not offer as much mechanical stability as the conventional cross-finger flap and has an arc of rotation that is slightly smaller than the conventional flap.2,3 Take-Away Messages Cross-finger flaps and reverse cross-finger flaps are extremely useful tools for reconstruction of small to moderate-sized defects. However, the surgeon should always weigh the options: whether involving a noninjured digit in the reconstruction process is indicated, or whether a homodigital solution is preferable. It is important to make the pedicle as robust as possible by including as many perforators as possible. The paratenon must be respected at all times.

The flap should be designed only slightly larger than the defect and must be sutured in under minimal tension. The flap can be protected by placing a thick “holding suture” through the pulp of the donor and recipient fingers. Any lateral movement of the fingers by the patient will be painful and will force the patient to halt this activity. “Buddy tapping” allows early active exercise of the fingers (usually after 3 to 5 days), helping to avoid adhesions and eventual limited active range of motion.

Care should be taken when using cross-finger flaps to reconstruct defects of the pulp. Usually the flaps are insensate, and it is often not possible to include a dorsal nerve branch into the flap. In more proximal uses, the dorsal nerve branch can be coapted to the stump of the proper digital nerve if a sensate flap is desired.
For defect reconstruction in the conventional cross-finger flap, a full-thickness skin graft is recommended. This can be taken from the ulnar border of the hand, just above the midline. This is an almost invisible donor site. The risk of problems when touching surfaces is low, since the scar is above the hypothenar contact zone. For skin coverage of the reversed cross-finger flap, a split-thickness skin graft is recommended.  

References


Bibliography With Key Annotations


The author described a new approach—double cross-finger flaps—for coverage of ring avulsion injuries. Twenty-two cases of ring avulsion injuries, with patients who met certain criteria, were operated on by this new technique. Two cross-finger flaps were harvested, one to cover the palmar aspect and the other to cover the dorsal aspect after being deepithelialized and turned over. A split-thickness graft was then applied to cover the raw areas. Both functional and aesthetic outcomes were reported after a mean of 6 months’ follow-up.


The “homodigital distally based” dorsal adipofascial flap has been used by various authors to cover small, complex, dorsal, digital defects. In 2004, Al-Qattan reported on 3 cases in which a distally based dorsal adipofascial flap was used in a cross-digital fashion. This report expanded on the concept of cross-digital adipofascial flaps in which the flaps are based not only distally but also proximally or laterally located. A total of 14 patients with complex dorsal digital defects were reconstructed with cross-digital adipofascial flaps. The main indication for using the cross-digital technique was a concurrent dorsal skin shear injury adjacent to the complex defect, which precluded the use of the homodigital technique. There were 11 males and 3 females, with a mean age of 27 years. All defects were located on the distal two phalanges of the digits. The adipofascial flap was based distally in 2 patients, laterally in 2 patients, and proximally in the remaining 10 patients. Six patients had associated extensor tendon injury. The cross-digital flap was covered with a split skin graft at the time of transfer, and its pedicle was divided 3 weeks later under local anesthesia. The mean follow-up time was 6 months. All flap survived, with no dehiscence or infection. One flap required regrafting at the time of flap
division. The mean total range of motion of the involved distal joint of the digit varied according to associated extensor tendon injury, from 60 degrees in patients with no concurrent tendon injury to 20 degrees in patients with segmental tendon loss requiring tendon grafts. Patients who had concurrent nail bed injury developed nail plate deformities such as thinning and ridging. One patient had nonadherence of the nail plate. All other patients were happy with the aesthetic appearance of the hand following reconstruction.


This article described a study comparing the results of two reconstructive options—the de-epithelialized cross-finger flap versus the adipofascial turnover flap—for coverage of small complex dorsal digital defects. Of 73 patients with small, complex dorsal digital defects, 31 underwent reconstruction with the de-epithelialized cross-finger flap and 42 had reconstruction with the adipofascial turnover flap. All flaps in both groups survived, with no infection or hematoma. Complications in the first group of patients included flap dehiscence (1 patient), considerable skin graft loss (2 patients), stiffness of the donor finger (5 patients), and an inclusion cyst (1 patient). The only specific complication for patients in the second group was the occasional epidermolysis of the skin of the donor site, which occurred in 6 patients. Patient dissatisfaction with the appearance of the donor site was documented in 10 patients in group 1 and none in group 2. The elective flap division in the cross-finger-flap group was considered a disadvantage in children because it required general anesthesia. The versatility of both flap techniques in digital reconstruction is confirmed; however, considering the type of complication and the need for general anesthesia in children for cross-finger-flap division, the adipofascial flap was determined to be superior in the following specific groups: children, older patients, and patients with osteoarthritis and multiple defects of adjacent border digits.


A series of 15 cases of distally based adipofascial flaps to cover dorsal digital defects was presented. All flaps were raised just superficial to the dorsal veins (and hence preserving some fat with the reflected flaps) rather than raising them at the subdermal plane. In 3 cases there was another injury proximal to the defect that precluded the use of an adipofascial turnover flap from the injured digit, so a distally based cross-finger adipofascial flap was used from the adjacent finger. In 4 cases, the flap was used to cover compound fractures. The results showed complete survival of all flaps without loss of the overlying skin graft and without epidermolysis of the donor skin, indicating that raising the flap just superficial to the dorsal veins does not affect the reliability of its blood supply, yet it enhances the blood supply of the reflected skin flaps. This series also showed uneventful healing of compound fractures covered by the flap, indicating the flap’s reliability for covering exposed fractures. Finally, the study demonstrated the feasibility of using the flap as a cross-finger flap.


Injuries to the dorsum of the finger are common. When combined with exposure of important deeper structures, flap reconstruction is necessary. The deepithelialized cross-finger flap is a good option for covering large dorsal finger defects. The authors perform this flap on six patients (two female, four male). No flap loss or infection occurred. All defects were covered adequately, and no donor site problems developed. One week after flap division, the function of the involved finger joints had the same range of motion as the contralateral finger joints. The authors concluded that the deepithelialized cross-finger flap is a safe method for coverage of large dorsal finger defects. The good postoperative range of motion supports the indication for this two-step reconstruction procedure.

Adequate coverage of dorsal finger wounds is often a challenge. The reversed cross-finger subcutaneous flap to cover defects on the dorsum of the phalanx constitutes an excellent option for coverage of wounds over the middle and distal phalanges of the index, middle, ring, and small fingers. It is an easy flap to perform and represents the authors’ first choice for covering such defects.


Traditionally, the cross-finger flap is elevated in the plane lying superficial to the extensor tendon. This damages the delicate subcutaneous tissues, which are important for the lengthening capacity of the skin of the dorsum of the fingers during flexion and extension. The authors presented a modification of elevation of the cross-finger flap in a plane superficial to the dorsal veins of the fingers. This modification prevents donor finger complications such as poor graft take, extensor tendon adhesion to the graft, reduced range of finger joint movement, and contour deformities. The authors reported their use of this technique in six digits in four patients with successful results.


The authors reviewed the results of cross-finger flaps in nine patients after surgical release and vigorous postoperative exercises for long-standing, severe flexion contractures of the proximal interphalangeal (PIP) joints of fingers. All contracted tissue was sequentially released and the resultant skin defect was covered with a cross-finger flap. The cause of the contractures was contact burns in four, skin grafts in three, and previous operations in two. The mean follow-up period was 41.2 months. The mean flexion contracture and further flexion in the joints were improved from 73.4/87.8 degrees to 8.4/95.4 degrees at the last follow-up. A mean of 19.5 degrees of extension was achieved, with vigorous extension exercise after the operation. The mean gain in range of motion was 79.4 degrees. Near full range of motion was achieved in three cases. There were no major complications.


The author discussed the salvage of degloved digits—class III ring avulsion injuries, per the Urbaniak et al classification—using the heterodigital neurovascular island flap originally developed by Moberg and Littler, in addition to full-thickness grafts. Six fingers with class III ring avulsion injuries were included. The volar surface was covered with a heterodigital island flap from the adjacent finger, and a full-thickness graft was applied to the dorsum. All flaps survived. The mean graft take was 85%, and mean static two-point discrimination was 8.3 mm. The mean total active range of motion in the digits with intact tendons was 190 degrees. In the digits with absent tendons, the total active range of motion was 90 degrees. Cold intolerance and cross-sensibility were reported in half the patients. Follow-up was from 6 to 42 months. The technique described is useful for salvaging degloved digits when replantation is not feasible and the patient refuses amputation despite careful counseling. However, donor finger morbidity is a major concern, and in this regard both patient and surgeon should consider the decision carefully.


Because relevant literature is scarce, this study was undertaken to assess the donor site morbidity of cross-finger flaps. It included 23 patients who had undergone reconstruction of a finger defect with a cross-finger flap. Any additional trauma to the donor finger was an exclusion criterion. Split-thickness skin grafts were employed for donor site closure in 13 cases, full-thickness skin grafts were used in 10 cases. Follow-up averaged 83 months. Active and passive total range of motion of the donor finger
and maximal pinch grip strength in kilopascals were measured. Both parameters were compared with the corresponding finger of the other hand. The donor site scar was evaluated for instability and pain in the donor finger was determined subjectively with a visual analog scale. Cold intolerance and the cosmetic appearance of the donor site were also assessed. Active total range of motion of the donor fingers averaged 156 degrees. Average active total range of motion of the contralateral control fingers was 173.6 degrees. There was a significant difference between the donor fingers and the control fingers, but not between split-thickness and full-thickness grafted donor sites. Grip strength was significantly impaired in the donor fingers, but there was no significant difference between split thickness and full thickness grafted donor sites. Subjective cosmetic evaluation by the patients revealed significantly better results for full-thickness grafted donor sites. Donor finger pain averaged 2.4, with a range of 0 to 8. Five of the 13 patients with split-thickness grafted donor sites and two of the 10 patients with full-thickness grafted donor sites mentioned cold intolerance. Although the cross-finger flap is a secure and valuable option, there is significant donor site morbidity. These results suggest that alternative solutions should also be considered, and if a cross-finger flap is employed, donor sites should be closed with full-thickness grafts.


The authors presented a prospective, nonrandomized study of 15 patients with large soft tissue defects of the fingertips. In all cases, the fingertips were reconstructed using a bilaterally innervated sensory cross-finger flap. This sensory fasciocutaneous flap relies on the dorsal branch of the proper digital nerves, which branch off at the level of the head of the proximal phalanx; sensory supply to the dorsal skin of the middle phalanx is thus ensured. The reconstructive procedure consists of two steps. First, the contralateral dorsal branch of the proper digital nerve is elevated with the flap at proximal interphalangeal joint level. Microsurgical coaptation is performed to the proximal nerve stump of the injured fingertip. After 3 weeks, when the pedicle is dissected, the second nerve is dissected and coapted. Clinical results were evaluated after 12 months. Because the regenerative distance is only 1.5 to 2.5 cm, good sensory regeneration should be expected. In nine of 16 flaps, sensory quality of S2+ (Highet) was present in the flap after 3 weeks. After 12 months, two-point discrimination was present in all patients, the values ranging between 2 and 6 mm (for two-point discrimination), with an average of 3.6 mm. The rate of complications was low. With acceptable additional operative action, a good functional result can be achieved.


The heterodigital arterialized island flap is a versatile flap providing robust, vascularized, non sensate soft tissue cover for the reconstruction of sizable digital defects. Routine inclusion of a dorsal vein augments venous drainage and minimizes postoperative congestion. The authors proposed a modification to extend the reach and versatility of the flap in resurfacing larger digital defects and defects in awkward areas such as the dorsal surface, distal fingertip, and far sides of border digits or thumb. They reviewed their experience with this technique in 12 patients with digital soft tissue defects. Defects ranged from 2.0 to 4.5 cm long and from 1.0 to 2.5 cm wide. By positioning the finger defect to the flap and creating a temporary bridging tissue pocket at the base of the fingers to site the flap pedicle, the flap was applied to defects of adjacent digits in a cross-finger fashion. Division and inset of the flap were performed 3 weeks later. Complete survival and primary healing was achieved in all the flaps, without evidence of venous congestion. Donor morbidity was acceptable. All donor fingers retained normal fingertip sensation and had minimal stiffness, with return of excellent to good total active interphalangeal joint motion.


The conventional cross-finger flap is indicated for soft tissue defects in the proximal or middle phalanges that are not suitable for skin transplantation. The reversed cross-finger flap is indicated for soft tissue defects in the dorsal proximal or middle phalanges that are not suitable for skin transplantation.
Contraindications include extensive tissue defects crossing the finger joints, and concomitant injuries of the neighboring fingers. The adipocutaneous flap is harvested from the dorsum of the finger to the midlateral line, preserving the paratenon of the donor phalanx. The flap is transferred into the defect of the neighboring finger, and the donor site is covered with a full-thickness skin graft. For the reversed cross-finger flap a subcutaneous flap is prepared, with preservation of the paratenon by separating a skin flap from the subcutaneous fat according to the “open book—closed book” technique. The flap pedicle is transected after 14 to 21 days. Both fingers are immobilized until the pedicle is transected. Active and passive physiotherapy exercises can be initiated after 5 to 7 days. The authors reported uneventful healing in 18 cross-finger flaps, resulting in an average DASH score of 18 after an average follow-up of 38 months. Twelve results were subjectively judged as very good or good; 16 patients complained about intermittent cold intolerance.


A reverse-flow cross-finger pedicle skin flap raised from the hemidorsum has been used that is a modification of the distally based dorsal cross-finger flap. The flap is raised from the hemidorsum at a plane above the paratenon; the distalmost location of the base is at the level of the distal interphalangeal joint. Thirty-two flaps were used from 32 fingers in 32 patients. Of these, 31 (97%) flaps survived fully; there was stiffness of finger in 1 (3%) patient. Two-point discrimination was 4 to 8 mm in 14. The patients were followed from 2 months to 3 years. The advantages of this flap are that there is less disruption of veins and less visible disfigurement of the dorsum of the finger compared with other pedicled cross-finger skin flaps. The disadvantage of this flap is its restricted width. It is recommended as the cross-finger pedicle skin flap of choice when the defect is not wide.


Various flaps have been described for reconstruction of soft tissue defects of the digits, but these are not applicable to all kinds of defects. Moreover, these techniques are mostly two-stage operations that require long-term immobilization. In this study, reverse-flow digital artery cross-finger flap was used to cover various volar and dorsal digital defects in nine cases. Seven of nine cases that were followed for more than 2 years were evaluated, and all had good results. The authors recommended the reverse-flow digital artery cross-finger flap as a universal flap that can be used for almost all types of soft tissue defects of the digits.

Shah SH, Thrumurthy SG. Re-establishing functionality and aesthetics after severe burns over the proximal interphalangeal joint using the cross-digital dorsal adipofascial flap. Burns 37:e16–e18, 2011.


The authors reported an exceptional case of complete cutaneous ring finger avulsion. The distal fragment was not replantable because of lack of vessels. The reconstruction restored a functional finger.


A case of circumferential digital skin loss with exposed tendons from the proximal phalanx to the distal interphalangeal joint was presented. This was treated with a two-layer heterodigital cross-finger (open book) flap from the adjacent digit, using a skin-only cross-finger flap to cover the palmar defect and an adipofascial flap to cover the dorsal defect.


The authors combined use of the cross-finger flap and the side-finger transposition flap to cover the skin and soft tissue defect created by contracture release of severely contracted fingers in eight patients with Stern type III flexion contractures of the proximal interphalangeal joints. The cause of injury was burn in six patients and trauma in two patients. The average follow-up period was 11.6 months. All
operations were successful. Lack of extension of the proximal interphalangeal joint was improved by approximately 81.2 degrees for all digits. Stern type III contracture of the proximal interphalangeal joint can be released by transverse incision and ample resection of scarred tissue, and the resulting palmar skin defect that cannot be covered by using the finger’s own flaps or cross-finger flap can be covered by combined use of cross-finger and side-finger transposition flaps.


Many regions of the hand are affected seriously in patients with complex severe postburn hand contractures. Multiple flap choices are available to treat complex severe postburn hand contractures effectively. The authors prefer the dorsal ulnar flap for the palmar region; the cross-finger flap, side-finger flap, and the combined use of both for flexion contracture of the fingers; and the rhomboid flap for web contractures. Eight patients with complex severe postburn hand contractures were treated. The maximum improvement of joint extension was 75 degrees for the metacarpophalangeal joint and 105 degrees for the proximal interphalangeal joint. The grasp function of the hand dramatically improved, and the bulk of the flap did not interfere with grasping.


Distal dorsal skin defects of the digits could be considered as a surgical entity. The coverage of this area is challenging because of the proximity of the distal interphalangeal joint, the thinness of the extensor apparatus, and the vicinity of the nail. The authors stated that among the numerous flaps described, the homodigital turnover pedicled flaps appear the most effective option rather than cross-finger flaps.


The authors reported their use of cross-finger flaps to repair palmar soft tissue defects of the finger in 25 cases (32 fingers) with tendon or bone exposed. There were 18 males and 7 females; they ranged from 13 to 45 years of age. The time from injury to diagnosis was 30 minutes to 48 hours. The tissue defect size ranged from 1.5 by 1.0 cm to 4.1 by 2.0 cm. All cases were treated with an emergent operation, and flap sensation was recovered by anastomosing the cutaneous branch of the ulnar digital finger and the distal digital nerve of injured finger. The flap pedicle was dissected 3 weeks later. Follow-up was conducted for 6 to 26 months; the cross-finger flaps all survived with full digital fingertips, satisfactory appearance, good function, and normal sensation. Two-point discrimination was 5 to 8 mm.


Volar-oblique injuries of the thumb pulp are particularly disabling. Many methods have been described to treat these injuries and provide return of sensibility. The conventional cross-finger flap is an established technique and is well suited for intermediate-sized partial pulp losses. The authors reviewed their experience with this flap and described technical refinements that have contributed to improved early outcome and long-term neurosensory recovery. Thirty patients underwent 31 cross-finger flaps to the thumb for volar-oblique pulp defects. Defect sizes ranged from 1.5 to 5 cm in length and 1.5 to 3 cm in width. Dorsal skin of the index finger proximal phalanx was used in 26 patients, the index finger middle phalanx in 2 patients, and the long finger middle phalanx in 3 patients. Nine patients were available for long-term follow-up and were subjected to functional assessment (DASH questionnaire), sensitivity testing (two-point discrimination, Semmes-Weinstein monofilament testing), and range of motion evaluation. Thirty of 31 flaps survived. In 1 patient, trauma to the attached flap from the long finger middle phalanx resulted in flap ischemia. This was revised with a fresh cross-finger flap from the index finger proximal phalanx. Employed patients were able to return to their original jobs. Recalled patients (9) were assessed at a mean of 29 months after surgery (range 12 to 70 months).
All recalled patients regained normal sensibility on two-point discrimination testing. Functional outcome was satisfactory in 8 patients (DASH score, 0 to 20). The last patient (DASH score, 61.67) complained of hypersensitivity and cold intolerance that affected his work.


The authors reported on their experience in treating 35 fingers in 30 patients with soft tissue defects at the dorsal side of digital interphalangeal joint and at the fingertips. These were repaired with the reversed artery cross-finger flap with a compound skin pedicle, 1.5 by 1.0 cm to 2.0 by 2.0 cm. All cases were followed for 1 to 6 months and evaluated clinically. All of the flaps survived, with good texture and no swelling; there were no adverse side effects at the donor site.


Digital replantations are often complicated by problems of venous congestion. Conservative management is not always successful. Furthermore, the skin edge around the replanted digit is frequently inflamed and necrotic, leading to difficulties in restoring venous flow by direct venous anastomosis or interpositional vein grafts. The authors introduced a novel solution using the proximally based cross-finger flap. They performed this flap in 10 patients who had venous congestion with inflamed, necrotic skin at their digital replant site. Their initial injuries were amputations. The flaps averaged 3.98 by of 2.59 cm and were harvested from the dorsum of the adjacent, uninjured digit. There was only one failure in a patient who had sustained a massive crush injury. Of the remaining 9 cases, 7 met or exceeded the sensory threshold (Semmes-Weinstein monofilament test). Results of the two-point discrimination test were less than 6 mm in 8 cases. Three patients complained of residual pain (based on the Michigan Hand Outcomes Questionnaire), and only one was unsatisfied with the resulting appearance. The proximally based cross-finger flap is pedicled and requires only a single level of venous anastomosis distally, leading to a higher success rate. It offers a simple yet effective solution for venous congestion.
ANATOMIC LANDMARKS

**Landmarks**
Volar skin and pulp of the overlying distal phalanx from the distal interphalangeal (DIP) joint crease to the injury site.

**Size**
1.5 × 2 cm.

**Composition**
Skin and volar pulp.

**Flap Type**
Cutaneous.

**Dominant Pedicle**
Terminal branches of both digital arteries.

**Nerve Supply**
Terminal branches of both digital nerves.
Section 9G

HAND

Kleinert-Atasoy V-Y Flap

CLINICAL APPLICATIONS

Regional Use
Coverage of transverse distal fingertip amputations
ANATOMY OF THE KLEINERT-ATASOY V-Y FLAP

Dominant pedicle: Digital artery with cutaneous branches to digital pulp

Fig. 9G-1
ANATOMY

Landmarks  Volar skin and pulp of the overlying distal phalanx from the DIP joint crease to the injury site.
Composition  Skin and volar pulp.
Size  1.5 × 2 cm.

Arterial Anatomy (Type A)

Dominant Pedicle  *Terminal branches of radial and ulnar digital arteries*
Regional Source  Common digital arteries derived from the palmar arch.
Length  5 to 10 mm.
Diameter  0.2 to 0.3 mm.
Location  Arising from the midlateral line and extending in a volar direction distally into the pulp.

Venous Anatomy

The venous anatomy follows the arterial circulation.

Nerve Supply

Sensory  Terminal branches of the radial and ulnar digital nerves arising from the common digital nerves in the palm. Source nerves are the medial and ulnar nerves, depending on the finger involved.

Vascular Anatomy of the Kleinert-Atasoy V-Y Flap

![Image of Kleinert-Atasoy volar V-Y flap incision](image1)

Kleinert-Atasoy volar V-Y flap incision

![Image of vascular supply to pulp](image2)

Vascular supply to pulp: Two digital arteries join to form common trunk

**Fig. 9G-2**

*Dominant pedicle: Branches of volar digital artery (D)*
FLAP HARVEST

Design and Markings

The flap is designed as a triangle, with its broad base forming the proximalmost extent of the fingertip amputation. The apex ends at the DIP joint crease, unless a more proximal extension is deemed necessary. It is preferable not to transgress the crease in an effort to reduce flexion contractures.

Patient Positioning

The patient is placed in the supine position, with the upper extremity extended in a supinated position on a hand table.

GUIDE TO FLAP DISSECTION

This procedure is easily performed with a local anesthetic using a proximal digital block. It is also feasible to perform this under local finger tourniquet control without having to resort to exsanguination of the upper extremity with a proximal arm tourniquet. The skin island is incised through the dermis until the pulp fat is visualized. With the entire skin island incised along its periphery, medial and lateral mesentery arteries should be preserved to maintain a robust blood supply to the flap. This is achieved by mobilizing the deep surface of the pulp fat off the periosteum of the distal phalanx and the flexor sheath of the insertion of flexor digitorum profundus.

At this point, the flap has been elevated off the underlying bony and tendinous structures and the skin island has been incised through the dermis, but the subcutaneous fat within the pulp should be intact along the entire periphery and proximal end of the flap. Although this will provide some distal movement of the flap, it does not allow adequate translocation of the flap over the distal phalanx to complete closure of the amputation site. To allow greater distal movement, the proximal attachments of the flap to the volar fat at the level of the DIP joint crease need to be divided. This can be undertaken by retracting the apex of the flap distally to expose the fat at the DIP joint crease, which is then carefully divided with either a No. 15 blade or fine scissors down to the flexor sheath, taking care not to damage the sheath itself.
The flap has now been released on its deep surface as well as proximally and is only attached on broad medial and lateral mesentery arteries consisting of fat containing both perforating vessels and nerve branches. These maneuvers will usually allow the flap to be pulled distally to cover the entire amputation site without difficulty. If tension is a problem, judicious release of the most proximal fibrofatty attachments can be performed while making every effort to maintain an adequate blood supply to the flap from either side.
**FLAP VARIANT**

**Kutler Bilateral Advancement Flaps**

The Kutler flaps were developed to provide lateral and medial skin and pulp for advancement into larger distal amputations or slightly oblique amputations unsuitable for a single Kleinert-Atasoy advancement. Like the Kleinert flap, each flap is based on its terminal perforating branches from the ipsilateral digital artery. The nerve supply is similarly based on the ipsilateral digital nerves. As described in the dissection for the Kleinert flap, Kutler flaps require supraperiosteal mobilization to allow distal advancement. Great care should be taken when mobilizing the base of the flap, because it is easy to impair the blood flow to these flaps with proximal detachment. Both flaps are advanced distally, and the wide bases are sutured together in the distal midline. One of the major disadvantages of this procedure is that the flaps tend to be smaller than the Kleinert V-Y flap, and multiple suture lines are present with potential for impaired sensory return and neurogenic pain.

**ARC OF ROTATION**

The Kleinert-Atasoy V-Y flap rarely advances more than 5 to 10 mm and can rotate over a curve of about 60 degrees.
FLAP TRANSFER
Having mobilized the flap, it is pulled distally with skin hooks and the distal base should be sutured to the dorsum of the injured finger at each corner. This will allow assessment of tension and the possible need for more proximal mobilization if necessary.

FLAP INSET
Flap inset is performed with interrupted 5-0 nylon or Prolene sutures starting with the distal end of the flap being sutured to the dorsum or the amputation site to set the flap tension.

DONOR SITE CLOSURE
The flap should be closed distally first, then the radial and ulnar borders are sutured to the adjacent skin. This maneuver produces a V-shaped donor site, which is closed longitudinally in the midaxis of the finger to achieve a Y-shaped closure.

V-Y closure

Fig. 9G-7
CLINICAL APPLICATION
This 21-year-old patient presented with her finger partially amputated.

Fig. 9G-8 A, The width of the nail bed was measured at the level of the amputation. B, The flap should be as wide as the width of the nail bed at the level of the amputation. C, The flap was undermined distally between the flap and the distal phalanx. D, The flap was advanced to cover the amputated fingertip. E, V-Y advancement of the flap. F and G, Final result of the fingertip after healing of the flap, showing good contour. (Case courtesy Amit Gupta, MD.)
Pearls and Pitfalls

- The flap is most useful for repair of clean, transverse guillotine type amputations of the distal fingertip.
- Volar oblique amputations encroach too much on the distal territory of the flap design and may require use of a Kutler flap, or a neurovascular island flap in the case of larger defects in critically important digits.
- Undermining must be done at the supraperiosteal level, not within the pulp fat of the flap.
- Medial and lateral mesentery arteries must be of adequate size to support viable vascular inflow. The overlying skin should only be incised through the dermis along the sides of the flap; the incisions should not extend into the substance of the fibrofatty pulp mesenteries.
- The proximal fibrofatty restraining bands must be carefully divided to prevent necrosis, but these bands must be adequate to allow distal advancement of the flap.
- Resection of distal bone can be considered to ensure tension-free closure.

EXPERT COMMENTARY
Amit Gupta, Basem Abdulla Attum

In 1935 Ettore Tranquilli-Leali reported a description of a volar V-Y advancement flap used for the repair of fingertip amputations. In 1970 Harold Kleinert and Erdogan Atasoy made some modifications to this flap to further increase the indications for this procedure. The main difference between the two flaps has to do with the vascular supply of the graft itself. The Kleinert-Atasoy flap is classified as an axial neurovascularized island flap. Perfusion of the Tranquilli-Leali flap occurs through the terminal segmental branches of the proper digital arteries, through the superficial dorsal arch to the proximal dorsal arch, then terminating through the fibroosseous hiatus branches. These flaps were created because previous methods were able to provide good padding and coverage, but they lacked normal sensation.

Fig. 9G-9  Vascular supply to the pulp of the digit showing the two digital arteries joining to form a common trunk and branches coming from the common vessel supplying the pulp.
Indications
Initially, bipedicled palmar advancement flaps were thought to be contraindicated in finger-tip reconstruction because the dorsal branches of the digital arteries at the proximal interphalangeal joint level were sacrificed; sacrificing these vessels significantly increased the risk of dorsal skin necrosis. This flap is used when the pulp defect is less than half the size of the distal phalangeal segment of the finger. For the flap to be effective, the injury should leave more pulp than nail bed.

Fingertip amputations can be classified into three different zones:
- Zone 1 injuries occur distal to the bony structures, and the phalanx is preserved. Most of the nail bed and the integrity of the matrix are preserved. This structure allows normal nail contours after healing. Treatment for zone 1 injuries is usually conservative; this may include secondary healing, meticulous wound care, and conservative debridement. Wound healing can be facilitated by the use of topical antibiotic ointments, with frequent monitoring of the injury to prevent overgrowth of excessive granulation tissue.
- Zone 2 injuries are typically located distal to the lunula of the nail bed. These injuries are also accompanied by bony exposure of the distal phalanx. Management of zone 2 injuries require a local or distant pedicle flap reconstruction.
- Zone 3 injuries involve the nail bed, with resultant loss of the entire nail bed. The most common treatment for zone 3 injuries is amputation. Because of the amount of trauma in zone 3 injuries, tissue reconstruction is not a reasonable treatment option.

Recommendations
Technique
It is best to perform this reconstruction under loupe magnification. This procedure can be best performed in 12 steps:
1. Perform a digital block using a combination of 1% lidocaine (Xylocaine) and 0.25% bupivacaine (Marcaine), both without epinephrine. I perform a digital sheath block. If it is felt that this injury will require extensive debridement, conscious sedation with midazolam (Versed) or monitored anesthesia with propofol (Diprivan) could be used. Alternatively, an axillary block anesthesia may be used.
2. Create a tourniquet effect by either using a small Penrose drain or a commercially available digital tourniquet at the base of the injured digit. I use a forearm tourniquet; I think this is less traumatic to the digital arteries.
3. Extensively irrigate the wound with normal saline solution.
4. Debride the devitalized tissue.
5. If there is a portion of bone that is protruding from the wound, trim it or remove it with the use of a rongeur. This will assist in the advancement of the V-Y flap.
6. Create a triangular advancement flap, with the base of the flap at the cut edge where the amputation occurred. This flap should be as wide as the widest part of the amputation (see Fig. 9G-8, A and B). The tip of the flap will extend to the distal finger crease (see Fig. 9G-8, B).
7. Make a full-thickness skin incision. I stretch the flap and press the full blade of a sharp No. 15 blade to the incision to sharply cut the pulp septa without subcutaneous undermining. Dissection may be performed with tenotomy scissors distally between the distal phalanx and the bone (see Fig. 9G-8, C) and proximally between the deep part of the flap and the flexor sheath. Doing this will help in the advancement of the flap (see Fig. 9G-8, D and E). Drs. Kleinert and Atasoy, who taught me how to do this flap, emphasized this step: “Dissect as much as you dare in this plane,
and then a little more.” Under no circumstance should subcutaneous undermining be done, because the vascular supply to this flap resides in this plane.

8. Advance the newly created flap over the defect and use either 5-0 or 6-0 chromic catgut to suture it to the nail bed.

9. Place corner stitches with 5-0 nylon to avoid interrupting the blood supply.

10. Convert the V-shaped defect into a Y-shaped defect (see Fig. 9G-8, E), suturing with 5-0 nylon.

11. Remove the tourniquet. At this point, take time to observe the capillary refill and color of the flap. Be aware that this process may take several minutes because of vasospasm. If 10 minutes have passed and capillary refill is still slow after that period, check the distal sutures, because they may be sutured too tight.

12. Apply antibiotic ointment over the sutures and cover the site with a protective splint of your choice.

**Advantages of the Flap**

There are many advantages of the V-Y plasty technique. First, technically it is simple to perform. Second, it is cosmetically favored, because scarring is kept to a minimum (see Fig. 9G-8, F and G). Patients report feeling less pain with this procedure, because the flap is not directly located over the end of the finger. This technique also gives the ability to preserve the normal contours of the dorsal finger and helps preserve the finger fat pad.

One of the main clinically significant advantages of this pedicle flap is the preservation of normal sensation and two-point discrimination. The V-Y plasty technique preserves the normal sensation of the finger. The main technical advantage of the Kleinert-Atasoy flap is that it is a bipedicled neurovascular flap. Since this flap is only attached by the neurovascular bundles, it can be advanced further than the Tranquilli-Leali flap. It can also be used for transverse and dorsal facing amputations, and palmar facing injuries that angle up to 30 to 35 degrees.

Postoperative management is simplified as well. Patients require only a simple finger dressing and guard without any immobilization. Historically, flaps required long-term immobilization.

Finally, this technique involves only the injured finger; this results in fewer operations. Finger stiffness that occurs with other flap techniques is prevented by the single-finger coverage flap. For this flap to be effective, there cannot be any other injuries proximal to the distal tip injury.

**Complications**

As with any procedure, complications do occur. Although infection is rare because this is a highly vascularized location, infection can occur between the distal phalanx and the flap, which can result in bone exposure. When this occurs, resection of the distal 2 mm of bone is performed, with readvancement of the flap in a second operation. If the dorsal branch of the digital nerve is resected, a neuroma can develop.

The main patient complaint is pain, and unfortunately, it has been shown that this pain does not decrease in intensity even after attempts to desensitize the nerve have been performed. Sloughing of tissue occurs if excess tension is applied or if there is disruption in the blood supply when undermining the flap. It has been reported that the nail may have an irregular contour without hooking. Another rare complication is sympathetic dystrophy, with hypersensitivity of the fingertip that usually responds to conservative treatment within a few weeks.
References


Bibliography With Key Annotations


Fingertip injuries can be treated in different ways, including shortening with primary closure, skin grafts, and local or distant flaps. Nail bed involvement complicates fingertip reconstruction and may influence the choice of treatment. Local flaps can usually replace the pulp and provide a satisfactory functional and aesthetic result, whereas reconstruction of the fingernail apparatus is more difficult. Between 1998 and 2001, 12 fingertip injuries with nail bed involvement were treated with a combination of local flaps (Tranquilli-Leali and Venkataswami flaps) and the eponychial flap. The eponychial flap described by Bakhach is a backward cutaneous translation flap that lengthens the nail plate and restores a good appearance of the nail apparatus. This technique is simple to use and can be used with different flaps for pulp reconstruction.


The authors retrospectively reviewed the cases of 14 fingertips reconstructed with a combination of local or regional flaps and nail bed grafts, some of which were placed wholly or partially over a deepithelialized flap. Most of the fingertips had sustained a crushing injury and were reconstructed at the time of the injury. Soft tissue coverage was provided by palmar V-Y flaps in 6 cases, thenar flaps in 4, lateral V-Y flaps in 2, a Moberg flap in 1, and a cross-finger flap in 1. Split toenail bed grafts were used in 6 cases, full-thickness nail bed grafts from the amputated part in 6, and split nail bed grafts from the injured digit in 2. There was 1 partial graft loss and 1 partial flap loss. The remaining cases had completely successful grafts and good soft tissue healing. Subsequent nail growth and adherence were good in all but the 1 digit requiring secondary composite grafting.


The authors presented a modification of the flap first described in 1935 by Tranquilli-Leali and described again by Atasoy et al in 1970. The relative indications for use of the original and the modified flap were examined in the light of the authors’ experience of 116 flaps over a period of 4 years.

V-Y plasty was performed in 28 patients who suffered from a transverse amputation of the fingertip. Bilateral V-Y plasty was carried out in 16 cases and single volar V-Y plasty in 12 cases. The average follow-up period was 32 months. Six patients had postoperative complications that required reoperation in four patients. The follow-up results were satisfactory. The results showed that V-Y plasty is indicated in transverse amputations through the distal third to half of the nail bed, but only in patients to whom the length of the finger is of importance.


The Tranquilli-Leali and Atasoy volar V-Y advancement flaps are considered workhorse flaps in the reconstruction of fingertip amputations. However, their description in the literature in terms of surgical dissection and blood supply is often indistinct. This study described the differences between the two flaps and highlighted their unique blood supply based on a thorough cadaveric study and review of the literature. Using 16 fresh cadaveric fingers, 8 Tranquilli-Leali and 8 Atasoy volar V-Y advancement flaps were dissected, mapping the arterial blood supply using an injectable blue resin. In all 8 fingertips dissected as described by Tranquilli-Leali, the flap was supplied by the anastomotic connections between the terminal branches of the palmar digital arteries and dorsal nail bed arcades via the fibroosseous hiatus. In contrast, in all 8 fingertips dissected as described by Atasoy, the flaps were perfused through the terminal branches of the palmar digital arteries. The Tranquilli-Leali and Atasoy volar V-Y advancement flaps, used to reconstruct fingertip amputations, are distinct from one another in several ways. The most obvious difference is their technique of flap dissection, which in turn dictates a unique blood supply.


Based on the transverse palmar branch of the digital artery, a flap was designed on the volar side of a digit and reversed to repair fingertip defects; 12 fingers in 11 patients were reconstructed using this flap. Eleven flaps survived and 1 necrosed. The contour of the reconstructed fingers was good. This new neurovascular island flap provides excellent padding and sensation for fingertip reconstruction, and the technique is simple.


From August 2001 to June 2005, 112 injured fingers were surgically treated in 108 patients (68 males, 40 females; ages 16 to 63 years). The patients underwent operations 2 hours after the injuries. Nine kinds of flaps were taken from the dorsal or volar aspect of the injured fingers to cover the defects of the distal fingers. The flaps were divided into two categories: (1) flaps that were nourished by the main digital arterial branches, including the V-Y island flap based on the digital neurovascular bundles, the reversed digital artery flap, the modified Moberg flap, and the twin flaps based on the digital general neurovascular bundles; and (2) flaps that were nourished by the collateral digital arterial branches, including the dorsoulnar arterial retrograde flap of the thumb and the reverse flap based on the dorsal branches of the digital artery, the volar flap based on the transverse palmar branch of the digital artery, and the island flap from the dorsum of the index finger and the digital local flaps. Follow-up ranging from 2 weeks to 8 months revealed that all the flaps survived, with the exception of flap necrosis in 3 patients and superficial necrosis in 3 patients. Sensation reached almost normal levels in the flaps based on collateral digital arteries, and two-point discrimination was between 5 and 10 mm in the flaps based on the arterial branches. Finger motion ability was good, and finger appearance was satisfactory.

Fingertip amputations are commonly seen by family physicians. The classification of fingertip injuries corresponds with the normal anatomy of the tip of the digit. There are three zones of injury; the V-Y plasty technique is used to repair zone II injuries. The plane of the injury can be described as dorsal, transverse, or volar. The dorsal and transverse planes lend themselves to the use of the V-Y plasty technique. In carefully selected injuries, the family physician can use this technique to repair the injured digit. The use of a single V-Y plasty has replaced the original technique that repaired the digit and restored the contour of the fingertip. Good cosmetic and functional results can be obtained. Complications may include flap sloughing, infection, and sensory changes.


The authors presented the cases of three patients in whom defects of the distal part of the dorsum of the finger were covered with a rotation flap or V-Y advancement flap based on a single perforating branch of the digital artery running from the volar to the dorsal side. This method is useful for the reconstruction of the distal dorsal region of the fingers, because the flap is more mobile, has a smaller skin island, and is less invasive compared with previous flaps. This type of flap conforms to the concept of a perforator flap arising from the main artery.


The authors described a new homodigital neurovascular island flap for fingertip reconstruction, called a volar digital island flap. The flap is perfused from the proper digital artery through the transverse palmar branch and is drained through the tiny venules and capillaries contained in the perivascula soft tissue. Between 1997 and 2000, 25 fingers from 23 patients with defects of the middle and distal phalangeal areas were reconstructed using this flap. All flaps survived well. Patients ranged in age from 17 to 65 years (average 32.5 years). Long-term follow-up for more than 6 months was possible in 15 fingers from 14 patients. Light touch and temperature sensation could be detected in all the flaps evaluated. The mean value of the static two-point discrimination test was 4.2 mm. Although this flap requires the sacrifice of important volar skin, it provides excellent padding and sensation for fingertip reconstruction. The authors presented this new flap as an alternative choice for coverage of fingertip defects.


The authors described a technique of using volar advancement flaps with V-Y closure to the fingers. It is possible to perform volar flap advancements up to 15 mm and use V-Y closures in the distal palm, avoiding a skin graft. This method is based on knowledge of the vascular anatomy of the finger dorsum, to avoid devitalizing dorsal skin. This method was applied to 14 fingers of 13 patients including finger amputations, claw nail deformities, and skin defects of the middle phalanx. Favorable results were observed.


The V-Y flap is indicated for reconstruction of transverse or oblique defects of the fingertip, including those with exposed bone of the distal phalanx. It is not suitable for larger defects of the phalanx over the proximal interphalangeal joint, crush injury of the finger, preexisting lesions of the fingertip, or in patients with circulatory disorders or contamination or infection of the finger. The authors described a single volar (Tranquilli-Leali, Atasoy) or a bilateral V-Y flap (Geissendorfer, Kutler) for restoration of the fingertip. The incision is V-shaped and is converted to a Y as the flap is advanced. The subcutaneous tissue of the flap contains neurovascular structures and provides sensibility and padding of the fingertip. A distal advancement of the flap up to 10 mm is possible with this technique. The finger is immobilized with a two-finger splint for 1 week. This approach produces good functional results.

The fingertip is an extremely specialized end organ with a highly developed sense of touch. The authors presented different ways of reconstructing a traumatized fingertip. They also explained the differential indications for the techniques available. The whole spectrum of fingertip reconstruction was discussed, starting from local neurovascular flaps (palmar V-Y Atasoy, Kutler, palmar Moberg, lateral Venkataswami and Subramanian, palmar Hueston), distant flaps (Littler, Foucher, dorsal metacarpal artery, cross-finger, reversed cross-finger), and free flap transfer (free toe-pulp transfer, spare-part transplantation). The advantages and disadvantages of each flap were highlighted. The authors presented an algorithm to help the surgeon determine the correct type of reconstruction.


Amputations of the fingertip are the most common injuries to the upper limbs, and they cause the greatest socioeconomic losses. The first choice of repair technique should be the simplest and fastest, with rapid restoration of function and an acceptable aesthetic appearance. The repair should return individuals to their jobs rapidly to prevent economic loss. Volar V-Y advancement flaps should therefore be considered first, but unless the dorsal loss is greater than the volar, this first choice of flap cannot be used because of the inadequate donor area. The authors presented a method for treatment of amputations that are proximal to the matrix of the nail. Seven volar oblique or transverse amputations were treated with dorsal V-Y advancement flaps with or without volar V-Y advancement flaps. All flaps survived. The procedure is simple, versatile, and a reliable way of reconstructing amputations of the fingertip that are proximal to the nail bed.


The traditional Kutler and Atasoy V-Y advancement flaps have minimal range of advancement, so they are not satisfactory for the repair of large skin defects in the fingers; hence there are limited indications for their use. The sensory function of the repaired fingers is impaired because of injury to sensory nerves and scar formation. From 1985 to 1991, the V-Y advancement flap with bilateral digital arteries and nerves as the pedicle was used for the reconstruction of 33 fingertip defects and 5 digital volar cicatricial contractures. Satisfactory results were obtained in all cases.


The author described an operation based on anatomic studies showing the pattern of the fibrous septa and neurovascular bundles of the distal phalanx. Lateral V-Y advancement flaps are outlined, with the dorsal incisions going sharply to the bone. With palmar retraction of each flap, dense fibrous bands on its underside are sharply divided. The palmar incision is made through skin only. The nerves, vessels, and adipose tissue of this pedicle are preserved while the fibrous septa are carefully divided. This technique permits 10 to 14 mm advancement of each flap. Complete division of the dorsal pedicle permits great mobility of the flap without functionally diminishing circulation or innervation. This procedure is particularly useful in traumatic fingertip amputations with the palmar and transverse oblique deformities. Elective remodeling of irregular fingertips has also been aided by this operation.


The volar V-Y plasty is a well-accepted method of management for transverse fingertip amputations. It has been suggested by some authors and assumed by some surgeons that fingertip sensation is nearly normal following the procedure. Sixteen patients with 20 fingertip injuries reported an average estimate of sensitivity of 73% of normal. There was diminished sensation to testing by two-point discrimination and/or von Frey monofilament testing in all fingertips when compared with the contralateral digit. Eight patients (12 fingertips) reported hypersensitivity, particularly cryalgia. The authors concluded that sensation is not normal in almost all fingertips treated by V-Y plasty for transverse amputations.
## ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>Flap is designed from the distal thumb tip to just proximal to the metacarpophalangeal flexion crease on the volar aspect of the thumb. Lateral flap borders are the midaxial line on the ulnar and radial aspect of the thumb.</th>
</tr>
</thead>
<tbody>
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<td>1 to 1.5 cm × 4 to 6 cm; essentially covers the whole length of the volar aspect of the thumb, with extension into the thenar space as needed.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Fasciocutaneous advancement or island flap.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type A.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Perforating branches of the ulnar and radial digital arteries of the thumb.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td>Digital radial and ulnar digital nerves arising from the median nerve sensory component.</td>
</tr>
</tbody>
</table>
Section 9H
HAND
Moberg Advancement Flap

CLINICAL APPLICATIONS
Regional Use
Thumb

With contributions by Michel Saint-Cyr, MD.
ANATOMY OF THE MOBERG ADVANCEMENT FLAP

A

Digital artery

Superficial and deep palmar arch with radial and ulnar artery contribution

B

Digital artery

Arterial supply to flap area: Perforating branches of ulnar and radial digital arteries of thumb

C

Ulnar digital nerve

Nerve supply to flap area: Radial and ulnar digital nerves arising from median nerve sensory component

Fig. 9H-1

**Dominant pedicle:** Ulnar and radial digital arteries of the thumb, perforating branches
ANATOMY

Landmarks  Flap is designed from the distal thumb tip to just proximal to the metacarpophalangeal flexion crease on the volar aspect of the thumb. Lateral borders of the flap are represented by the midaxial line on the ulnar and radial aspect of the thumb.

Composition  Fasciocutaneous advancement or island flap.

Size  1 to 1.5 cm x 4 to 6 cm; essentially covers the whole length of the volar aspect of the thumb, with extension into the thenar space as needed.

Arterial Anatomy (Type A)

Dominant Pedicle  Perforating branches of ulnar and radial digital arteries of the thumb

Regional Source  Superficial and deep palmar arch with radial and ulnar artery contribution.

Length  5 mm for the perforating vessels.

Diameter  1 mm for the digital arteries; 0.2 to 0.3 mm for the perforating branches.

Location  Digital arteries of the thumb lie in a more volar position than do the digital arteries of the fingers. The same is true of the digital nerves. The vessels lie at least 5 mm volar to the midlateral line of the thumb on either side.

Venous Anatomy

The flap is drained by venae comitantes running parallel to the digital artery as well as a subcutaneous venous plexus within the volar subcutaneous tissue of the thumb. The thumb can be considered to have an independent dorsal blood supply provided by the dorsalis pollicis artery branch, which is a branch of the radial artery. This independent blood supply allows safe mobilization of the volar advancement flap without compromising the thumb’s dorsal blood supply, unlike the fingers, which rely on dorsal branches of the digital artery for their dorsal blood supply. All fingers except the small finger have an independent dorsal blood supply that terminates at the proximal phalanx. Distal to this, the dorsal branches of the palmar proper digital arteries, which can be found at the proximal and distal interphalangeal joints, provide the dorsal blood supply. Therefore advancement of flaps in a digit other than the thumb must preserve at least one side of the dorsal branches of the proper digital artery to maintain adequate skin perfusion distal to the proximal phalanx.

Nerve Supply

Sensory  Digital radial and ulnar digital nerves arising from the median nerve sensory component.
Vascular Anatomy of the Moberg Advancement Flap

Deep surface of Moberg volar advancement flap

Closeup view of flap base

Fig. 9H-2
Dominant pedicle: Digital artery (D)

FLAP HARVEST
Design and Markings
The midaxial skin incisions are marked just dorsal to the neurovascular bundle on the radial and ulnar aspects of the thumb. These markings extend from the wound edge distally up to the metacarpophalangeal (MCP) joint flexion crease proximally on the volar aspect. For an extended palmar advancement flap variant, the incision would follow through proximally over the thenar eminence in a V fashion to provide additional advancement. Alternatively, Burow’s triangles can be marked at the base of the flap to allow further distal advancement.

Fig. 9H-3
Moberg volar advancement flap design
**Patient Positioning**
The patient is placed in the supine position with the arm abducted, extended and stable in supination, on a hand table.

**GUIDE TO FLAP DISSECTION**
Flap elevation proceeds from distal to proximal. Bilateral midaxial incisions are made dorsal to the neurovascular bundle to incorporate the radial and ulnar neurovascular bundles within the flap design. Distally, the midline of the flap and subcutaneous tissue is dissected off the periosteum of the distal phalanx of the thumb and off the flexor tendon sheath of the flexor pollicis longus tendon. Dissection continues in an areolar tissue plane just above the flexor tendon sheath; both neurovascular bundles are identified bilaterally during the early distal dissection. The midaxial incisions are adjusted as needed, and both neurovascular bundles must be included in the flap for proper vascularity.

Dissection of the Moberg flap continues proximally and encompasses the entire volar skin of the thumb, which is separated from the underlying flexor tendon sheath and periosteum. The flap can also be converted to an island flap by cutting the base of the Moberg flap over the volar aspect of the MCP joint. This will provide additional advancement without the need for acute flexion of the interphalangeal (IP) joint, which can lead postoperatively to flexion contracture and stiffness. Any dorsal branches from either the ulnar or radial digital arteries are ligated if they interfere with advancement of the Moberg flap. The thumb has an independent blood supply originating from the branch from the indicis pollicis and can tolerate bilateral sacrifice of both neurovascular bundles because of its independent blood supply from the indicis pollicis.

If the flap is elevated as a neurovascular island advancement flap, the two neurovascular bundles are not skeletonized, and a generous cuff of fibrofatty tissue is kept surrounding the pedicle and neurovascular bundles proximally bilaterally to minimize any risk of vasospasm. The flap is then advanced as needed over the distal tip defect and sewn above the nail bed, to allow for soft tissue contracture and to prevent a hook-nail deformity. Therefore over-correction is required by 2 or 3 mm to account for postoperative contraction of the flap.

![Bilateral midaxial incisions for advancement flap](image1)

![Flap and subcutaneous tissue dissection](image2)

**Fig. 9H-4**
If the flap is advanced as a pure advancement flap, the donor site does not require closure, and the midaxial lines are closed with either permanent or nonpermanent simple sutures under minimal tension, so as to not create any ischemia during flap insetting. If additional advancement is required in the form of an island flap, the proximal defect is closed with either a split-thickness or full-thickness skin graft or a triangular transposition flap; these are proximally based and are designed off of the ulnar and radial aspects of the thumb.

**FLAP VARIANTS**

- Cupped Moberg flap for increased volume in the digital pulp of the thumb
- Extended Moberg flap or extended palmar advancement flap of the thumb
- O’Brien modification of the Moberg flap

**Cupped Moberg Flap**
To maximize volume and tissue, the distal portion of the Moberg flap can be cupped and the raw edge of the distal portion of the flap allowed to heal by secondary intention to provide better padding and contouring to the reconstructed pulp of the thumb. Overprojection and overadvancement are required to allow for secondary contraction from an open wound.

**Extended Palmar Advanced Moberg Flap**
If additional advancement is required, a triangular V extension is performed over the thenar eminence and the skin of the thenar eminence in conjunction and continuity with the Moberg flap. The donor site is closed in a V-Y fashion to provide support for the V-Y closure, and the skin overlying the thenar space and thenar muscle are elevated above the fascia.
**O’Brien Modification**

In the O’Brien modification, the Moberg flap is transformed from a volar advancement flap to a volar island flap. The donor site is closed with either lateral triangular transposition flaps or with a full-thickness skin graft (see Fig. 9H-4, B and D).

**ARC OF ROTATION**

This is an advancement flap; therefore the arc of rotation is somewhat limited.

![Diagram of flap transfer and inset](image)

**FLAP TRANSFER**

Fine single skin hooks are placed at the distal corners of the flap, and distal traction is used to advance the flap over the distal aspect of the thumb. Further proximal release can be performed as indicated. In addition, some degree of IP joint flexion will allow a more tension-free closure at the risk of increasing permanent flexion contracture of the thumb.

**FLAP INSET**

The flap should be inset over the transverse or volar oblique amputation, with overprojection of the flap above the nail bed to minimize soft tissue contracture and to avoid any nail bed deformities that would result in a “parrot-beak” overhang in subsequent nail growth. The flap should be advanced and inset under minimal tension, and the IP joint can be flexed temporarily to off load any tension on the flap inseting. This can be corrected with progressive night splinting with the thumb in extension over the next 6 weeks after surgery.

**DONOR SITE CLOSURE**

The donor site is closed with nonabsorbable 5-0 or 4-0 nylon or Prolene. As with all intrinsic hand flaps, the site should not be closed under tension to minimize any risk of ischemia.
CLINICAL APPLICATIONS
This 56-year-old man presented with a transverse amputation of the right thumb.

Fig. 9H-6  A, Transverse amputation of the right thumb. B, The Moberg thumb palmar advancement flap for reconstruction of distal tip amputations. Midaxial lines are drawn on the ulnar and radial aspects of the thumb, and dissection is performed from distal to proximal until enough flap advancement is possible for distal coverage. C, The Moberg flap will allow more than 1 cm of volar advancement for distal tip coverage. Note that this advancement is done without IP joint flexion and that further mobilization would be possible with IP joint flexion. D and E, The patient is seen 1 year postoperatively with good contour and stable coverage of the distal thumb tip and pulp. Note the slight shortening of the amputated thumb. Range of motion and two-point discrimination are normal. (Case courtesy Michel Saint-Cyr, MD.)
This 16-year-old patient had right thumb pulp atrophy and constant pain with contact following a crush injury to the thumb.

Fig. 9H-7  A and B, The patient had right thumb pulp atrophy and constant pain with contact following a crush injury to the thumb. C and D, The Moberg flap was elevated, incorporating both neurovascular bundles into the flap. E, The flap was incised proximally and converted from an advancement flap to an island flap to achieve further reach for tension-free coverage. Any closure of the flap under tension may result in a hook-nail deformity. F, The end of the Moberg flap was cupped in shape to provide better volume, projection, and padding for the distal thumb tip. This was then left to heal by secondary intention. G, Lateral triangular transposition flaps were used to cover the exposed neurovascular bundle following flap advancement. (Case courtesy Michel Saint-Cyr, MD.)
This 35-year-old man had lost the volar 1.5 cm of his thumb pulp in an accident with a wood-splitter.

**Fig. 9H-8**  
A, The O’Brien bipedicled flap was modified to include a V-Y advancement flap at the base. B, This allowed advancement of the flap without the need for excessive IP joint flexion or skin grafting, so the base of the flap could be closed primarily. C, Final appearance of the thumb 4 months postoperatively with good cosmesis and sensation, and no IP contracture. (Case courtesy Steven L. Moran, MD.)
Pearls and Pitfalls

- The Moberg flap has an extremely robust and dependable blood supply with vascular anatomy that is straightforward and well known to all hand surgeons. Dissection should start from distal to proximal to better identify the neurovascular bundle distally. This flap must be harvested with the neurovascular bundles left intact within the flap design.
- Flexion of the IP joint may be required to assist in closure of the defect and to provide better advancement of the Moberg flap. The Moberg flap is notorious for causing IP joint contracture of the thumb. This is particularly true in patients over age 35, in whom any degree of prolonged joint flexion is likely to cause a permanent flexion contracture. If flap advancement is limited and does not provide enough mobilization for thumb tip coverage, the four following procedures can be performed to overcome this.
  - The interphalangeal joint of the thumb can be flexed as necessary and may be pinned in a position of flexion as needed to provide better flap immobilization. A progressive static extension splint will be required, once the flap heals, to address any flexion contracture of the IP joint. This is rarely a significant problem.
  - The incision can be extended from the volar metacarpophalangeal crease into the palm and thenar space. This creates a longer flap, which can be advanced. The donor site is closed in a V-Y fashion, or it can be closed with the use of two small triangular transposition flaps or rotation flaps.
  - The two Burow’s triangles can be excised at the flap base to facilitate advancement of both sides of the flap.
  - An incision can be made on the volar aspect of the MCP joint at the base of the flap to convert the flap into an advancement island flap with the donor site covered with a full-thickness skin graft.

EXPERT COMMENTARY
Michel Saint-Cyr

Indications
The Moberg flap or palmar advancement flap is a classic volar flap that replaces glabrous skin with like glabrous skin for transverse and volar oblique defects of the distal thumb. This maintains the length of the thumb and provides immediate two-point discrimination, replacing like with like. The skin texture, color, and sensitivity of the flap are identical to that of the native thumb skin. When considering this flap, the surgeon can anticipate advancement of 1 to 2 cm; any larger defect needs to be covered with either a pedicled radial forearm flap or a free wrap-around toe flap.

Recommendations

Technique
The midaxes of the ulnar and radial aspects of the thumb are marked dorsal to the neurovascular bundle bilaterally, which in this case corresponds to the incision line and dorsal limits of the flap. Before flap elevation, integrity of the princeps pollicis must be con-
firmed, so as to not jeopardize the independent blood supply of the thumb. The flap is then elevated off the periosteum of the distal phalanx and the flexor tendon sheath of the flexor pollicis longus distally. Dissection is then carried ulnarly and radially to identify the neurovascular bundle on both sides, and the midaxial incision on both the ulnar and radial aspects of the thumb are adjusted as needed based on location of the neurovascular bundle distally. A lateral incision of the flap is made with a No. 15 blade, which can also be used to dissect the flap off the flexor pollicis longus flexor tendon sheath, with care taken not to damage the flexor tendon sheath.

The neurovascular bundle is irrigated with papaverine during dissection to minimize any vasospasm, and the midline incisions are carried down all the way to the volar proximal flexion crease. A V-Y tip of the flap can be performed for smaller defects, although I prefer using the whole volar aspect of the thumb for advancement to minimize any risk of vasospasm of the neurovascular bundles. Once the volar base of the MCP joint has been reached, the IP joint can be flexed slightly to see whether this is all that is needed for proper tip coverage. If significant advancement is still required, I do not hesitate to make a transverse incision at the volar base of the MCP joint to convert the flap from an advancement flap into an island flap. This can provide an additional 1 cm of advancement without creating a significant donor site deficit. A full-thickness skin graft can be used to cover the donor site, or the donor site can be closed with lateral triangular transposition flaps.

The flap is then inset under minimal tension, which is critical, so as to not create any ischemia, and the IP joint is kept in flexion as needed, with no forceful extension until indicated. The flap is then immobilized for 1 week with soft dressings with the hand in the position of function and with flexion of the IP joint of the thumb to minimize any risk of extension and flap ischemia. The distal portion of the flap can be trimmed and contoured to provide a nicely rounded thumb profile and distal tip.

EXPERT COMMENTARY

Steven L. Moran

Personal Experience and Insights

Clinically, I have found applications of the classic Moberg flap limited to closure of small defects less than 1 cm in diameter. To enhance the flap’s utility and avoid the necessity of creating an IP flexure contracture, I have opted to use a technique shown to me by David Elliot, which is a modification of the O’Brien advancement flap. The proximal portion of the flap is designed in a V fashion, extending proximal to the thenar eminence. This then allows V-Y closure of the base of the defect without an additional skin graft or lateral transposition flaps (see Fig. 9H–8). With this modification the flap can be advanced 1 to 2 cm without the necessity for IP joint flexion to provide wound closure. Care is taken to position the midaxial incisions dorsal to the lateral IP joint creases to prevent the scar from developing across the thumb pulp.
Other options for thumb tip coverage, such as the first dorsal metacarpal artery island flap and the Littler flap, require reinnervation or recortication to restore thumb sensation. The Moberg flap allows immediate sensation, restoration of glabrous skin, and a reasonable cosmetic result.

Reference

Bibliography With Key Annotations

The palmar thumb advancement flap was first described by Moberg in 1964. This article focused on a refinement of the palmar thumb advancement flap technique that involves augmenting the digital tip with an autogenous dermal graft. This dermal “padding” is placed directly over the bony tuft to act as a shock absorber, adding bulk and contour to the distal tip of the finger, increasing soft tissue stability, eliminating direct percussive tenderness of the bone, and decreasing disability for specific occupations such as those requiring typewriting. Six cases were reported.


The authors reported on use of the Moberg palmar advancement flap for pulp reconstruction of the thumb in 36 cases. No flaps were lost. Eighty-three percent of the defects were closed without additional iatrogenic bony shortening of the thumb. At a mean of 27 months, sensory testing showed normal sensitivity in 74% of the 25 patients studied. Minor restrictions in active range of motion in the interphalangeal joint were mainly attributable to a loss of hyperextension. No thumbs developed permanent flexion contracture. The flap alone did not result in a reduction in grip strength, but an additional bony amputation resulted in decreased strength of three-point pinch grip. Seventy-two percent of the patients had no or only mild subjective complaints. The Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, which was used for the first time as a standardized measure to assess functional outcome after this procedure, showed only minor impairment levels. The authors concluded that the Moberg advancement flap remains the procedure of choice for covering defects of the distal palmar thumb.


The author presented a technique that permits resurfacing up to 3 cm of palmar skin loss from the thumb while preserving thumb length, minimizing thumb joint flexion contracture, and providing normal sensibility. The classic Moberg palmar advancement flap is extended proximally onto the thenar eminence. The radial and ulnar defects created by the distal advancement of the flap are closed by two additional local rotation flaps. Scarring is acceptable and follows natural lines. The technique is applicable to both primary repair and secondary reconstruction.

The commonly used variant of Moberg's advancement flap for thumb reconstruction requires a skin graft to reconstruct the proximal thumb defect after advancing the flap. A modification described previously allows direct closure of this proximal defect by incorporation of the V-Y principle into the design of the proximal part of the flap. This article presented a variant of the V-Y Moberg flap.


The authors reviewed their experience with 13 neurovascular palmar flaps for thumb tip coverage: 6 O'Brien and 7 Moberg flaps, with a mean follow-up of 81 months. Both techniques were found to be safe and effective in preserving pulp sensibility, with a mean two-point discrimination of 5 mm and a Semmes-Weinstein score identical to that of the contralateral side in 9 cases. The interphalangeal joint retained a normal range of motion and did not seem to be affected by the perioperative flexion.

The main residual complaints were persistent cold intolerance (present in all cases and severe in 3), pulp instability (present in 6 and severe in 2), and nail deformity. This last problem was more related to the injury. Despite these drawbacks, the authors concluded that O'Brien and Moberg flaps remain their first choice for coverage of 1 to 2 cm pulp defects of the thumb.


Large soft tissue defects of the pulp of the thumb and fingers may be successfully covered using the palmar advancement flap described by Moberg, which is based on both neurovascular pedicles. In a series of 21 cases, the authors found no shortcomings with regard to sensibility, padding of the distal phalanx, or joint function. In 50% of the cases, however, there was a deformity of the nail and dysesthesia in the region of the hyponychium.


The Moberg volar advancement flap has been used to restore normal sensation to soft tissue deficits of the thumb. Application of this same technique for fingertip injuries was later suggested by Snow, but differences in digital blood supply led to dorsal tip necrosis and selection of other reconstructive techniques by many surgeons. Other methods have the disadvantages of widened two-point discrimination, a tender pulp scar, or an unacceptable donor site scar. The volar advancement flap applied to fingers restores normal to near-normal sensation and adequate pulp with minimal deformity. The authors stated that preservation of the dorsal perforating vessels was most important in successfully executing this procedure. In their cases, no dorsal tip or flap necrosis occurred. Two-point discrimination was normal or within 2 mm of contralateral values in every digit. Full range of motion, or less than 5 degrees of extension loss, was recorded in all fingers that were normal before operation. The authors suggested that this is a safe and effective adjunct in the treatment of fingertip injuries.


The authors discussed their preferential indications for repairing cutaneous loss of the thumb. The choice of the flap depends on localization. To repair a frontal amputation, a triangular volar flap (Atazoy) was performed; to repair a tangential distal amputation, a neurovascular island flap (O'Brien-Moberg) was used. To repair a tangential palmar amputation, a flap with advancement and rotation (Hueston) was performed. A free toe-to-fingertip neurovascular flap was necessary to restore sensation after complete avulsion of pulp. The island kite flap transfer from the dorsum of the index to the thumb (Foucher) was used to repair loss of the dorsal and palmar side of the first phalanx. For tangential dorsal amputation, cross-finger and free toe to thumb “custom-made” transfers were possible.

The volar advancement flap of the thumb described by Moberg has been used for pulp defects up to 1.5 cm; its mobility is limited by the stiff nature and fibrous connections of the regional skin with underlying structures. There have been several attempts to increase the mobility of this useful flap by adding V-Y and Z-plasty concepts into the technique. However, these modifications have provided only a slight increase in flap advancement and achieved closure of defects up to 2 cm in length at best. This article described the island volar advancement flap of the thumb in which all attachments except the neurovascular pedicle of the flap are divided to provide maximum mobility and advancement. The authors used the technique in 12 patients for reconstruction of traumatic defects of the distal thumb up to 3.5 cm in length. The flaps healed uneventfully in all patients. There were no flap failures. All patients were followed for 2 to 6 years. The authors concluded that the island volar advancement flap seems to be a safe and useful procedure for thumb reconstruction.


This article presented a series of 54 patients in which full-thickness soft tissue defects on 57 digits were reconstructed using homodigital V-Y flaps. This is a modification of the Moberg procedure, which was designed for coverage of injuries of the distal thumb. The V-Y flap is pedicled on two digital neurovascular bundles, possible advancement is up to 2 cm, and the V-shaped base of the flap allows direct closure of the proximal defect, without skin grafting. This technique was used for the reconstruction of both volar and dorsal tissue defects of the fingers. All flaps healed within 2 to 4 weeks. Fourteen patients (15 fingers) were evaluated after they recovered. In all affected fingers, active range of motion was satisfactory, with only slight defect of extension in 2 cases. However, sensation of light touch was decreased in 10 fingers, and two-point discrimination was abnormal in 5 fingers. The authors concluded that the V-Y technique is versatile in various clinical occasions, is easy to learn, and has a low risk of complications.
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Chapter 10

Abdomen

The abdomen provides the largest volume and surface area of tissue of all areas of the body for both local and distant reconstructive applications. Locally, it provides unique solutions for recurrent ventral hernia and complex abdominal wounds. In particular, the rectus abdominis complex has a wide range of uses for breast, chest wall, and pelvic reconstruction, and, like the latissimus dorsi flap of the back, it is one of the most ubiquitously used flaps. In an effort to limit abdominal wall morbidity, the abdomen has been the front line in the development of perforator-based flaps.

Deep Circumflex Iliac Artery (DCIA) Flap
Rectus Abdominis and TRAM/DIEP Flaps
External Oblique Flap
Superficial Inferior Epigastric Artery (SIEA) Flap
Groin Flap
Thoracoepigastric (Transverse Abdominal) Flap
Pudendal-Thigh (Singapore) Flap
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>The anterior superior iliac spine (ASIS), the pubic tubercle, and the curve of the iliac crest are the major landmarks for this flap.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>16 × 12 cm.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Osteocutaneous, osseous muscle, and myocutaneous.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type I.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Deep circumflex iliac artery and vein arising from the external iliac vessels.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td>Sensory: T12.</td>
</tr>
</tbody>
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Section 10A

ABDOMEN

Deep Circumflex Iliac Artery (DCIA) Flap

CLINICAL APPLICATIONS

Distant Use
- Head and neck
- Breast
- Upper extremity
- Lower extremity

Specialized Use
- Mandible
- Breast
Fig. 10A-1

Dominant pedicle: Deep circumflex iliac artery
ANATOMY

Landmarks  The ASIS, pubic tubercle, and curve of the iliac crest are the major landmarks for this flap. This composite flap comprises the anterior iliac crest extending posteriorly from the anterior superior iliac spine, with the overlying skin and portions of contiguous muscles.

Composition  The flap may be raised as a composite osteocutaneous flap or a soft tissue-only myocutaneous or perforator flap.

Size  16 × 12 cm. A bony segment measuring up to 18 cm may be elevated; the 12 × 6 cm skin island may be included. For breast reconstruction, the skin island is larger and extends beyond the iliac crest onto the flank.

Arterial Anatomy (Type I)

Dominant Pedicle  Deep circumflex iliac artery

Regional Source  External iliac artery.

Length  6 to 8 cm.

Diameter  2 to 2.5 mm.

Location  The deep circumflex iliac artery (DCIA) arises from the lateral aspect of the external iliac artery near the origin of the deep inferior epigastric artery. It then courses laterally toward the ASIS between the transversalis fascia and the transversus abdominis muscle. Just medial to the ASIS, a large ascending branch courses superiorly through the transversus abdominis muscle and then along the deep surface of the internal oblique muscle, which it supplies. Lateral to the ascending branch, the DCIA courses through the transversalis fascia along the inner lip of the iliac crest. Here it lies in the line of fusion between the iliac muscle and fascia transversalis. During this course along the iliac crest, the branches of the DCIA supply the adjacent muscles and the overlying skin. The artery eventually reenters the transversus abdominis muscle, where terminal branches anastomose with branches of the iliolumbar and superior gluteal artery.

Venous Anatomy

A single vein accompanies the arterial circulation with an average venous diameter of 1.5 to 2.5 mm.

Nerve Supply

Sensory  T12 (a branch of T12 supplies the skin portion of this flap).
VASCULAR ANATOMY OF THE DEEP CIRCUMFLEX ILIAC ARTERY (DCIA) FLAP

Deep surface of osseous muscle flap

Radiographic view

Deep surface of osteomyocutaneous flap

Radiographic view

Fig. 10A-2

Dominant pedicle: Deep circumflex iliac artery (D)
mc, Myocutaneous perforating vessels; arrows, periosteal vascular connections
FLAP HARVEST

Design and Markings

The skin island is designed as an ellipse extending from the ASIS along the curvature of the iliac crest. The island is centered along the iliac crest. For breast reconstruction, the island extends posteriorly to the posterior axillary line. The cutaneous perforators are clustered in an area measuring 6 by 4 cm just above the midpoint of the iliac crest some 5 cm posterior to the ASIS. Preoperative computed tomographic angiography (CTA) can help identify these vessels.

The skin design incorporates an extension of the incision made in the inguinal crease, extending from the femoral pulse laterally to the ASIS. This allows exposure of the proximal pedicle. If bone without overlying skin is to be harvested, the incision is extended laterally along the curvature of the iliac crest for the required distance (see Fig. 10A-5, A). For breast reconstruction, the skin island extends farther laterally and posteriorly to the posterior axillary line. If a skin island is elevated, then the proximal border of the skin island begins just past the ASIS.

Myocutaneous flap skin island design

Fig. 10A-3
Patient Positioning
The patient is placed supine on the operating table. Elevation of the buttock on a beanbag or slight rotation of the pelvis toward the opposite side will facilitate flap dissection. This is particularly useful when the flap is harvested for breast reconstruction.

Fig. 10A-4  A, Positioning for a combined ipsilateral harvest and breast reduction. B, The ipsilateral buttock is elevated on a pillow, rotating the pelvis.
GUIDE TO FLAP DISSECTION

Osseous Flap

After the inguinal crease skin incision is made, the dissection continues through the subcutaneous tissues and the external oblique aponeurosis is identified. Laterally, the external oblique muscle is identified and the tensor fascia lata is identified below the iliac crest.

The distal extent of the bone harvest depends on reconstructive requirements but usually extends to the posterior axillary line.

The external oblique aponeurosis is identified and split just above and parallel to the inguinal ligament.

The dissection is continued up to the level of the ASIS. Just proximal to the ASIS, the lateral cutaneous nerve of the thigh is identified as it courses downward from the lateral abdomen into the thigh.
Medial and upward retraction of the spermatic cord or round ligament of the uterus will expose the external iliac artery and vein. The DCIA can be identified as it takes origin from the external iliac artery and is traced laterally. The fibers of the internal oblique and transversus muscles are divided, and the vessel is followed laterally to the level of the ASIS, where the ascending branch is easily identified and divided.

![Fig. 10A-5 C](image)

*Fig. 10A-5 C,* Division of the internal and transversus muscles with lateral dissection of the pedicle. Note the division of the ascending branch of the DCIA.

The DCIA is dissected as it courses laterally along the curvature of the iliac crest. Just below the vessel the iliac fascia and muscle are divided, thus exposing the inner surface of the ilium.

![Fig. 10A-5 D](image)

*Fig. 10A-5 D,* Intrapelvic course of the deep circumflex iliac artery along the rim of the iliac crest. The line denotes the level of the iliacaus muscle division, sparing the vessel with the harvested flap.
Dissection continues until the desired length of iliac crest is reached. The distal end of the DCIA vessel is divided and the borders of the iliac crest to be harvested are identified. If the full-thickness iliac crest is required, the tensor fascia lata and gluteus medius are dissected from the lateral border of the iliac crest in the subperiosteal plane.

The bone is then ready for the osteotomies to complete elevation of the bone. If the entire thickness of the bone is not required, the tensor fascia lata and gluteus medius need not be detached, and only the inner table of the iliac bone is harvested. An oscillating saw is used to divide the bone. The ASIS should be spared. If only the inner lip of the iliac crest is harvested, the flap is far less bulky and the donor site deformity is less noticeable.

**FLAP VARIANTS**

- Composite osteomyocutaneous flap
- Myocutaneous flap
- Perforator DCIA flap
- Internal oblique flap
Osteomyocutaneous Flap

When bone, soft tissue fill, and skin for lining or resurfacing are required, a composite osteomyocutaneous flap can be harvested. The skin island is designed along the iliac crest extending from the ASIS posteriorly for the desired length. After identification of the vascular pedicle, as previously described, the skin island is incised and the upper half of the skin flap is directed down toward the iliac crest. Approximately 3 to 4 cm above the crest, the three layers of the abdominal musculature are divided, leaving a 2 to 3 cm cuff of muscle with the skin flap attached to the underlying muscle and bone.

Similarly, along the inferior border the skin is incised and a portion of the tensor fascia lata and gluteus medius muscles is included with the skin island and iliac bone. The remainder of the dissection is similar to that for the osseous flap.

Fig. 10A-6  A, Release of the tensor fascia lata and gluteus medius for a full-thickness osseous flap. B, Dissection completed. C and D, Variations in iliac crest bone harvest design for mandibular reconstruction.
Fig. 10A-7  **A**, Division of the ilioc crest fascia and muscle. **B**, Retroperitoneal dissection to the deep margin of the iliac crest. **C**, Deep surface of the flap within the retroperitoneal space. **D**, Completion of retroperitoneal dissection.

**Dominant pedicle:** Deep circumflex iliac artery (D)

- a, Anterior superior iliac spine; e, external oblique aponeurosis; i, internal oblique muscle; p, pubic tubercle; v, vascular pedicle to internal oblique muscle; t, iliacus muscle.
Fig. 10A-7

**Dominant pedicle:** Deep circumflex iliac artery (D)

a, Anterior superior iliac spine; c, deep circumflex iliac vein; p, pubic tubercle
**Myocutaneous Flap**

Also known as the Rubens flap, this variant’s skin island is larger and is designed to incorporate the maximum volume of lower lateral abdominal and flank fat. It can extend well beyond the iliac crest onto the lower back.

The initial groin incision is made and the pedicle is identified and traced to the ASIS. At this stage, a larger cuff of muscle is included with the pedicle. The skin island is then completed and the upper half of the island dissected off the external oblique muscle down to within 5 to 6 cm of the iliac crest. Here the upper half of the dissection extends through the external oblique, internal oblique, and transversus muscles. This compound myocutaneous flap contains perforating vessels into the overlying skin. These perforators are preserved and muscle is dissected to the iliac crest below the course of the DCIA pedicle. The lower half is then elevated off the tensor fascia lata and gluteus medius to the lower border of the iliac crest and over the crest and down along the periosteum of the inner surface of the crest. Perforating osseous branches of the DCIA are divided during this part of the dissection. Laterally, the skin and fat beyond the iliac crest are elevated as a fasciocutaneous extension. The dissection is deep to the fascia, up to the level of the iliac crest, and then deep to the muscles, as previously described. Final muscle flap elevation is completed by dissecting the muscles and pedicle off the inner surface of the iliac crest.

**Perforator DCIA Flap**

The flap can be raised as a cutaneous perforator flap based on the variable perforator supply identified by preoperative multidetector CT angiography (MDCTA). As many as 40% of patients do not have usable single perforators, and the traditional myocutaneous dissection has to be used in these cases. Perforators are centered in a 6 by 4 cm area just above the midpoint of the crest, approximately 5 cm posterior to the ASIS.
The dissection for this flap is identical to that for a myocutaneous flap initially. Once the ASIS is encountered, the vessels are dissected from the surrounding muscle fibers using gentle bipolar cautery dissection. The location of the perforators will have been determined by preoperative MDCTA. The skin island can be raised and subcutaneous dissection carried out directly over the crest until the appropriate vessel is reached. The two dissections are communicated with bipolar cautery, leaving the bulk of the muscle attachments to the crest only minimally disturbed. Repair can be undertaken as indicated once the flap is lifted from the wound.

**Internal Oblique Flap**

Based on the constant ascending branch of the DCIA near the ASIS, the internal oblique muscle can be harvested in part to add a component of muscle to an osseous or osteocutaneous flap. This extra muscle can be valuable for hardware coverage, intraoral lining, or soft tissue fill. The muscle as harvested has no muscular function.

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**Fig. 10A-10**  
A, After release of the internal oblique muscle from the iliac crest, the ascending branch of the DCIA is seen, here as two branches running under the muscle. B, Closeup view. C, Composite osteocutaneous flap with additional internal oblique muscle.  
**Dominant pedicle:** Ascending branch of DCIA (D)  
a, Anterior iliac spine; b, DCIA terminal branch to iliac bone; c, deep circumflex iliac artery;  
e, external iliac artery; p, pubis
Using the skin design and incisions previously described, the muscles are released from the iliac crest and the DCIA identified. Rather than divide the ascending branch, the space between the transversalis and internal oblique muscles is developed, following the ascending branch. Next the space between the exterior and interior oblique muscles is bluntly developed. The internal oblique muscle can then be harvested, maintaining the attachment of the vascular pedicle.

**ARC OF ROTATION**
This composite flap is primarily used as a free flap for microvascular transplantation. Any local flap would have its rotation point at the takeoff of the DCIA.

**FLAP TRANSFER**
The flap is transferred to its recipient site and secured before microvascular anastomosis based on the location of the defect.

**FLAP INSET**
Following microvascular transplantation the flap is inset into the defect. When a vascularized segment of iliac bone is included, the bone is inset and fixated with plates and screws before completion of the microanastomosis. Muscle and skin are then sutured into the defect site.

The internal oblique flap is carefully inset with particular attention to the pedicle of the internal oblique muscle to prevent any tension or torsion, especially around the bone.
DONOR SITE CLOSURE

Osseous and Osteomyocutaneous Flap

Closure of the donor site must be performed carefully to prevent postoperative deformity and hernia formation. When full-thickness bone has been harvested, the iliac muscle and fascia should be sutured to the transversalis muscle and fascia. The next layer, the internal and external oblique muscles, should then be sutured to the gluteal and tensor fascia lata muscles. The inguinal ligament should be repaired and the skin closed. If the entire thickness of the iliac crest is being harvested, a noticeable contour deformity will be present.

![Fig. 10A-11 A, Approximation of the iliac muscle and fascia with the transverse muscle and transversalis fascia. B, Approximation of the internal and oblique muscles with the gluteal and tensor fascia lata muscles. C, Repair of inguinal ligament. NOTE: Only nonabsorbable sutures should be used to repair the muscle donor site.]

When only the inner table of iliac crest has been harvested, the only muscles needing reattachment and closure are the external oblique, internal oblique, and transversalis muscles. This is accomplished by suture anchors or drill holes through the iliac crest. Because the outer table of bone is preserved, muscle contour deformity is minimized.

![Fig. 10A-11 D, Abdominal muscles sutured to the iliac crest with nonabsorbable sutures placed through a series of drill holes in the crest. Alternatively, suture anchors can be used.]

Myocutaneous Flap

Because no bone is resected, donor site closure is straightforward and there is minimal to no deformity. The internal oblique, external oblique, and transversus muscles are reattached to the iliac crest with permanent suture and/or suture anchors. A drain is placed.
Internal Oblique Flap
The external oblique should be carefully repaired back to the inguinal ligament and iliac crest using nonabsorbable sutures or suture anchors. If muscle harvest has weakened the remaining fascia and it does not hold sutures well, mesh should be added as an overlay to secure abdominal integrity.

CLINICAL APPLICATIONS
This woman developed cancer of the right breast for which she had a total mastectomy, chemotherapy, and radiation. She had had a previous abdominoplasty. She underwent breast reconstruction with a free right inferior gluteal flap that failed. A second gluteal flap was performed, but this also failed. She was then referred for a second opinion. Despite her abdominoplasty, she had fullness over her flanks and was deemed a suitable candidate for a DCIA (Rubens) myocutaneous flap reconstruction from the left hip.

![Fig. 10A-12](image)
A, The patient is shown preoperatively. B, The DCIA flap was designed. C, The donor site was closed. No bone was taken. D, She is shown 9 months after a successful free left DCIA flap to the right breast, which has produced good shape and symmetry. Her breast is soft and supple. E, The posterior view of the donor site shows minor distortion from the DCIA harvest. Most of the deformity is from her previous inferior gluteal flaps. (Case supplied by G.J.)
This 62-year-old man, an ex-smoker, developed a right intraoral squamous cell carcinoma of the floor of the mouth. A resection was performed, including a right rim mandibulectomy, followed by radiation therapy. Three years later, he developed osteoradionecrosis of the right mandibular body, with an external draining sinus. He was referred for a right hemimandibulectomy and composite free flap reconstruction. A composite osteocutaneous DCIA flap was planned.

Fig. 10A-13  A, A reconstruction plate was prepared before bony resection to maintain proper contour. B, Flap harvest. The DCIA and DCIV were identified at the donor site. C, The flap consisted of 8 cm of bone stock, which was secured to the reconstruction plate. Microscopic anastomosis to the neck vessels was performed. D and E, He is seen 1 year postoperatively with good mandibular symmetry and contour. There were no hernias or bulges at the donor site. (Case supplied by GJ.)
This man presented with squamous cell carcinoma of the right mandible. He underwent a right segmental mandibulectomy and neck dissection. Immediate reconstruction was performed with a split-thickness osteocutaneous perforator DCIA flap, using the inner table of the iliac crest to replace the right hemimandible, from the symphysis to the angle. No osteotomies were required to approximate the shape of the missing mandible.

**Fig. 10A-14**  
A, Dissection of a right osteomyocutaneous DCIA flap for right hemimandibular reconstruction. B, Rigid fixation of the DCIA flap from the mandibular symphysis to the right mandibular angle. C, DCIA skin paddle used to reconstruct the floor of the mouth. D, Postoperative appearance. E, Postoperative donor site appearance. (Case courtesy Matthew M. Hanasono, MD.)
This man, a bilateral below-knee amputee, presented with a floor of the mouth squamous cell carcinoma that had invaded the anterior mandible. A segmental mandibulectomy was performed. Mandibular reconstruction was performed with an osteocutaneous perforator DCIA flap. The full thickness of the iliac crest was used to approximate the thickness of the anterior mandible and to allow later placement of an osteointegrated implant. A closing wedge osteotomy was needed to restore the curvature of the left anterior mandible. Although only a small cuff of muscle was taken around the two perforators, the skin paddle was extremely bulky and required further thinning.

Fig. 10A-15  A, Anterior mandibular defect after resection of a squamous cell carcinoma. A right DCIA flap was planned. B, Right osteocutaneous DCIA perforator flap, with a cuff of muscle around the perforators. C, Because of the patient's body habitus, the skin paddle was still very bulky and needed to be thinned. D, Early postoperative appearance with the mouth open, showing the skin paddle. (Case courtesy Matthew M. Hanasono, MD.)
This patient presented with an orocutaneous fistula and osteoradionecrosis of his mandible, which had already been debrided from ramus to ramus. He had severe peripheral vascular disease affecting the lower extremities bilaterally. Bilateral split-thickness osseous DCIA flaps were used to reconstruct the left and right hemimandibles. Reconstruction of such an extensive defect was not possible with bone from a single DCIA flap. Because of size and complexity, the anterior cutaneous and floor of the mouth mucosal defects were reconstructed with an anterolateral thigh perforator flap.

Fig. 10A-16  A, The patient is seen before reconstruction, following debridement. B, Dissection of a right osseous DCIA flap. C, Inset of bilateral osseous DCIA flaps to restore the right and left mandible. D, Postoperative appearance, including reconstruction of the chin skin with an anterolateral thigh perforator flap. (Case courtesy Matthew M. Hanasono, MD.)
** Pearls and Pitfalls **

- Meticulous layered closure of the donor defect is essential to avoid herniation of the abdominal wall. It is preferable to drill holes in the iliac crest or use suture anchors and sew the muscles back with large-caliber nonabsorbable sutures.
- Mesh should be considered an option to support donor site closure.
- Preservation of the outer lip of the iliac crest will help minimize the donor site deformity. The DCIA supplies the inner lip and cortex of the iliac crest, the gluteal artery supplies the outer lip and cortex of the iliac crest; however, the DCIA can carry both cortices.
- The lateral cutaneous nerve of the thigh courses downward medial to the ASIS. It should be identified and preserved during flap dissection to preserve thigh sensation.
- If a perforator flap is raised, the perforators should be found clustered in an area measuring about 6 by 4 cm, starting approximately 5 cm posterior to the ASIS. Preoperative MDCTA is helpful in determining perforator caliber and location.
- The DCIA is an excellent source of small, vascularized bone grafts with generous pedicles for use in the extremities and head and neck.
- After the bone is harvested, especially in the case of a split iliac harvest, the exposed cancellous bone is harvested and bone wax is used to aid in hemostasis. The cancellous bone is used to pack around hardware and osteotomy sites.

** EXPERT COMMENTARY **

Matthew M. Hanasono

** Indications **
The osseous deep circumflex iliac artery (DCIA) flap has most commonly been used for mandibular reconstruction, and occasionally for maxillary reconstruction. The osteomyocutaneous variant of this flap allows for simultaneous mucosal or cutaneous reconstruction for these same defects. Use as a pedicled flap for acetabular reconstruction has also been described. The curved nature of the iliac crest generally limits its usefulness in reconstruction to shorter defects of the spine, tibia, or humerus, although osteotomies can be done to straighten the bone. The myocutaneous DCIA flap can be used in the reconstruction of virtually any soft tissue defect. Although less popular than the transverse rectus abdominus myocutaneous (TRAM) flap or deep inferior epigastric perforator (DIEP) flap, the myocutaneous DCIA flap (Rubens flap) is a reasonable option for breast reconstruction in patients with ample lateral lower abdominal skin laxity and subcutaneous fat for breast reconstruction.

** Advantages and Limitations **
The osseous and osteomyocutaneous DCIA flap provides very thick bone stock of reasonable length, which is particularly desirable in mandibular and maxillary reconstruction when osseointegrated implants are planned. The natural curvature of the bone is well suited to hemimandibular reconstruction, usually without the need for osteotomies. For flaps with a cutaneous component, the skin paddle size can be ample, depending on abdominal and flank laxity, which is usually desirable in breast reconstruction. The donor site can be well concealed, even in a bathing suit, especially when bone is not removed and the skin paddle size is not excessive relative to the patient’s body habitus.
Skin paddle thickness can also be a limitation of this flap, particularly when an intraoral mucosal defect is being reconstructed since a bulky soft tissue reconstruction may make flap inset challenging as well as obstruct the airway. In many cases, intraoperative or delayed flap thinning may be necessary, particularly when a denture or implant-retained prosthesis is planned. Obesity can also make exposure challenging during flap dissection, and in some patients, preclude the use of this flap. Although a long length of bone can theoretically be harvested (up to 16 to 18 cm), much of that bone is curved, limiting the osseous flap's usefulness when linear defects more than about 10 to 12 cm in length are being reconstructed.

**Anatomic Considerations**

In addition to the anatomic considerations mentioned in the chapter, the secondary blood supply to the cutaneous portion of the DCIA flap includes the superficial circumflex iliac artery (SCIA) and vein (SCIV), which arise from the femoral artery and vein, respectively. These vessels, which travel within the skin anterior to the anterior superior iliac spine (ASIS), may be used to augment the vascularity of the DCIA skin paddle. Also, the lateral femoral cutaneous nerve courses along the inner surface of the iliacus muscle and penetrates the deep fascia of the thigh about 2 cm inferomedial to the ASIS. The DCIA usually crosses over the lateral femoral cutaneous nerve near the ASIS, and care should be taken to avoid injuring it, which could result not only in numbness but also occasionally in dysesthesias.

**Personal Experience and Insights**

The osteomyocutaneous DCIA flaps can be very useful for reconstruction of composite head and neck defects. However, an excessively thick skin paddle in many patients often makes this flap a second line choice following the fibula flap, which usually has a much thinner skin paddle. Harvest of the cutaneous component as a perforator flap substantially decreases the bulk of this flap and provides greater freedom with respect to inset of the skin paddle. Experience suggests that a single skin perforator is usually adequate to support a skin paddle of about 10 by 15 cm. Thinning of the skin paddle by careful removal of the deeper layer of fat, below Scarpa’s fascia is usually safe, particularly if minimal thinning is performed in the region of the perforator itself.

Anterior mandibular defects require closing wedge osteotomies of the iliac bone to recreate the curvature of the anterior jaw. Lateral mandibular defects often do not require any osteotomies due to the natural curvature of the iliac crest. Harvest of the bone flap as a split-thickness flap based on the inner (deep) cortex of the iliac crest bone decreases the donor site morbidity while still providing ample bone stock that can tolerate osteotomies due to the robust periosteal blood supply from branches of the DCIA. If osseointegrated implants are planned, however, either a full-thickness bone flap or a partial full-thickness bone flap, incorporating the entire thickness of the superior “lip” of the iliac crest is preferred.

The soft tissue myocutaneous or cutaneous perforator DCIA flap is usually a secondary option in breast reconstruction, since most patients carry greater amounts of redundant skin and excess adipose tissue in the midline. One option for increasing the size of the soft tissue flap is “supercharge” the flap by including and anastomosing the SCIA, either to a separate recipient vessel or by leaving enough length on the ascending branch of the DCIA to anastomose to the SCIA. The deep circumflex iliac vein (DCIV) is usually adequate to provide drainage to the entire flap, although the SCIV can also be anastomosed to a second recipient vein, should venous congestion occur.
Recommendations

Planning

As mentioned in the chapter, perforator anatomy can potentially be visualized preoperatively using multidetector CT angiography (MDCTA).\(^1\) In addition to confirming the presence of a dominant perforator and its location, the patency of the DCIA pedicle is also verified. In the author’s experience, many patients who have peripheral vascular disease affecting their lower extremity circulation and precluding use of the fibula flap, also have compromised flow to the DCIA flap.

As described in the chapter, the skin paddle is centered along the superior border of the iliac crest, beginning in the region of the ASIS. The cutaneous perforators are located about 2 to 3 cm cephalad to the iliac crest, beginning about 5 cm posterior to the ASIS. The largest perforator is usually the most anterior. When a dominant perforator is present, it can be used as the sole blood supply to the skin paddle in the perforator flap variant.\(^2,3\) In addition to MDCTA, a handheld Doppler ultrasound probe can be of assistance in locating the perforator during operative dissection (Fig. 10A-18).

Fig. 10A-17  A, Skin markings for the planned flap, including the location of a cutaneous perforator (indicated by an X at the center of the flap design), localized with a handheld Doppler ultrasound probe, about 6 cm posterior to the ASIS. B, The cutaneous perforator is visible through the fascia, indicated by the forceps. C, Fully dissected osteocutaneous DCIA perforator flap.

References

The internal oblique muscle can be harvested in place of an excessively bulky skin island, with the iliac crest bone as part of a chimeric myoosseous flap, or in addition to the skin island as a part of a chimeric osteomyocutaneous flap.\(^4\) The internal oblique component is based on the ascending branch of the DCIA, which is found in close proximity to the ASIS. This is usually within 1 cm, and rarely more than 2 to 4 cm away, before it enters the DCIA into the fibroosseous tunnel formed by the line of attachment of the transversalis fascia and the iliacus fascia on the medial surface of the iliac bone.

**Technique**

The external oblique muscle and fascia are incised in the direction of their fibers to expose the internal oblique muscle. The ascending branch of the DCIA lies on the deep surface of the muscle. Dissection is performed from superior to inferior, taking care not to divide the intercostal neurovascular structures that supply the rectus abdominis muscle.

When a split iliac crest flap has been designed, the lateral and inferior borders of the bone flap are cut along the inner table of the bone with a cutting burr, creating a trough that goes full-thickness through the cortical bone. If the ASIS does not need to be included in the flap design, the medial extent of the bone flap can also be defined with a cutting burr, about 1 cm lateral to the ASIS, preventing disruption of the inguinal ligament. In these cases, the pedicle must be elevated away from the medial iliac bone and protected during the osteotomy. Next, the superior bone is osteotomized, splitting it along the upper lip of the iliac crest with an oscillating saw and entering the medullary space.

Control of bleeding with bone wax and use of large-caliber closed suction drains is recommended. Meticulous closure of the abdominal wall is required to prevent a hernia. Reinforcement of the closure with bioprosthetic mesh may also be advantageous in increasing the strength of the donor site closure.

**Postoperative Care**

Patients are mobilized within a few days of surgery and encouraged to ambulate with full weight-bearing as tolerated.

**References**

Bibliography With Key Annotations

Anatomic Studies

These two articles included the original anatomic studies and description of the DCIA flap. The clinical article described reconstruction of the mandible and extremities using this flap. The authors demonstrated that the DCIA supplies the bone, surrounding muscles, and overlying skin. In fact, these authors stated that the DCIA is a better source of blood supply for the skin over the iliac crest than the superficial circumflex iliac artery.


This clinical-anatomic study reported on the location and size of perforators arising from the DCIA axis. The authors noted that modifications to flaps based on DCIA perforators have been sought to prevent donor site morbidity as a consequence of muscle cuff harvest. Previous anatomic studies have been inconsistent in their descriptions of perforator anatomy. A cohort of 44 hemiabdominal walls in 22 consecutive patients undergoing preoperative computed tomographic angiography (CTA) before free flap surgery was evaluated. The use of CTA was shown to demonstrate DCIA perforators with high resolution and was able to assess vessel size and location. In 44 hemiabdominal walls, there were 44 perforators larger than 0.8 mm diameter. No suitable perforators existed in 40% of sides, with 32% of sides having one perforator larger than 0.8 mm diameter, 16% having two perforators, less than 10% had three perforators, and only one side had over four perforators. Perforators emerged from the deep fascia on an average of 5.1 cm cranial and 3.9 cm posterior to the anterior superior iliac spine (ASIS). Of the 44 perforators identified, 82% were located within a 4 by 4 cm area, 3 cm superior, and 2 cm posterior to the ASIS. The authors affirmed the usefulness of CTA in assessing which patients are suitable candidates for perforator DCIA flaps given the variability of the vascular anatomy.

Clinical Series

The authors described their experience with 8 DCIA flaps for maxillectomy defect reconstruction. The deep circumflex iliac artery (DCIA) flap has distinct advantages regarding the volume and length of the bone in reconstruction. The contour of the iliac bone is similar to the maxilla, providing good aesthetics, and bone volume allows placement of osseous-integrated implants for dental rehabilitation. They presented 8 cases of maxillary reconstruction using this flap (3 osteocutaneous and 5 osseous flaps) for benign and malignant maxillary disease, highlighting the variable vascular anatomy, difficulty of harvest, and the need for meticulous planning.


The authors reported on 35 patients who had undergone mandibular reconstruction with vascularized iliac crest. The evolution of the technique in the authors’ hands was outlined. They had three anastomotic failures and no donor site complications.

The role of the iliac crest as a vascularized free flap based on the DCLA for reconstruction of bony defects in long bones and the mandible was reviewed.


This was a retrospective review of 60 vascularized iliac crest free tissue transfers for oromandibular reconstruction. Flap survival was 95%, and the functional rehabilitation in 86% of the patients surviving intraoral cancer was good. Complications were reported as general complications in 15 patients, recipient site complications in 22 patients, and donor site complications in 21 patients. The authors concluded that aesthetic and functional results depend largely on three factors: the extent of the surgery, the weight of the patient, and the surgeon’s learning curve.


The authors presented two cases reconstructed with this variable composite flap. One patient had a complete heel defect produced by shrapnel injury. The complete calcaneus, soft heel, and Achilles tendon were reconstructed. The second patient had an empty os calcis after a comminuted fracture and a lateral crush-induced soft tissue defect. In both patients, stable wound closure, osseous integration, and weight-bearing ambulation were achieved.


Forty-one osteomyocutaneous flap procedures for reconstruction of the mandible and maxilla were reported. In 38 of the patients an osseous aluminum oxide implant in the vascularized bone graft was used to restore teeth.

### Flap Modifications


In a review of donor site options the “Rubens flap,” a modification of the DCIA flap, is presented. It is essentially a DCIA flap with no bone. In selected patients, especially those who have had an abdominoplasty or failed TRAM flap, this makes an excellent alternative to thigh and buttock tissues. The author emphasizes suturing the external oblique, internal oblique, and transversus muscles to the iliac crest to avoid postoperative hernias.

### Complications


In a retrospective summary of 78 patients who had undergone 82 free vascularized iliac crest tissue transfers the most frequent problems were described as early postoperative pain and long-term sensory changes. Major complications such as femoral neuropathy and incisional hernia were infrequent. Twenty-seven percent of patients complained of pain in the early postoperative period, 27% had late sensory changes, and 9.7% had hernias. The authors concluded that the donor site morbidity associated with the free vascularized iliac crest is well tolerated and the functional loss associated with the procedure is acceptable.
ANATOMIC LANDMARKS

Landmarks
A vertically oriented abdominal muscle extending between the costal margin and the pubic region.

Size
Muscle: 25 × 6 cm; 45 × 20 with skin paddle.

Origin
The muscle has two tendons of origin: the crest of the pubis and the symphysis pubis.

Insertion
The muscle inserts in three fascicles into the cartilages of the fifth, sixth, and seventh ribs.

Function
The rectus abdominis muscle flexes the vertebral column and tenses the abdominal wall, aiding in flexion of the trunk; it also plays a role in oblique tilting and rotation of the trunk.

Composition
Muscle, myocutaneous, and perforator skin only.

Flap Type
Type III.

Dominant Superior Pedicle
Superior epigastric artery.

Dominant Inferior Pedicle
Deep inferior epigastric artery.

Minor Pedicle
Segmental intercostal perforators (seventh through twelfth).

Nerve Supply
Motor and Sensory: Seventh to twelfth intercostal nerves.
Section 10B

ABDOMEN

Rectus Abdominis and TRAM/DIEP Flaps

CLINICAL APPLICATIONS

Regional Use
- Anterior thorax
- Abdomen
- Groin and perineum

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Breast
- Vagina reconstruction
ANATOMY OF THE RECTUS ABDOMINIS AND TRAM/DIEP FLAPS

Fig. 10B-1

**Dominant pedicles:** Superior epigastric artery; deep inferior epigastric artery
ANATOMY

Landmarks  This vertically oriented abdominal muscle extends between the costal margin and the pubic region. It is a long, flat muscle with three tendinous intersections located at the level of the umbilicus, the xiphoid process, and midway between the xiphoid process and the umbilicus. The inscriptions are visible in thin or muscular individuals.

Composition  Muscle, myocutaneous, and perforator skin only.

Size  Muscle: $25 \times 6$ cm; $45 \times 20$ cm with skin paddle.

Origin  The muscle has two tendons of origin: the crest of the pubis and the symphysis pubis.

Insertion  The muscle inserts in three fascicles into the cartilages of the fifth, sixth, and seventh ribs.

Function  The rectus abdominis muscle flexes the vertebral column and tenses the abdominal wall, aiding in flexion of the trunk; it also plays a role in oblique tilting and rotation of the trunk.

Arterial Anatomy (Type III)

Dominant Superior Pedicle  *Superior epigastric artery*

**REGIONAL SOURCE**  Internal mammary artery.
**LENGTH**  2 to 3 cm (can be extended with proximal dissection).
**DIAMETER**  1 to 2 mm.
**LOCATION**  Enters muscle on its deep surface after emerging from beneath the lowermost costal cartilages.

Dominant Inferior Pedicle  *Deep inferior epigastric artery*

**REGIONAL SOURCE**  External iliac artery.
**LENGTH**  6 to 10 cm.
**DIAMETER**  1 to 2.5 mm.
**LOCATION**  Enters the muscle on its deep surface at the lateral border at or just below the level of the arcuate line.

Minor Pedicle  *Segmental intercostal perforators (seventh through twelfth)*

**REGIONAL SOURCE**  Terminal branches of the intercostal arteries
**LENGTH**  2 to 3 cm.
**DIAMETER**  0.5 to 1.5 mm.
**LOCATION**  Segmental distribution passing from the linea semilunaris inferolaterally to enter the muscle on its posterior surface at the junction of the middle and lateral thirds. Attempting to carry the flap on its minor pedicle is not recommended, because its perfusion alone is inadequate.
Venous Anatomy

Paired veins accompany both the superior and inferior epigastric vessels. Superiorly, one vein predominates as the vessel transitions to the internal mammary vein, which is 1 to 4 mm in diameter. Inferiorly, veins combine to form a large single vein before entering the external iliac system. Diameters range from 2.5 to 4.5 mm.

Nerve Supply

**Motor**
Mixed segmental nerves from the seventh through twelfth intercostal nerves enter the deep surface of the muscle at its mid to lateral aspect. Motor and sensory branches split within the muscle to supply the muscle and skin, respectively. The inferiormost motor branch is responsible for innervation of much of the distal muscle. While segmental branches may be divided with some functional loss, during perforator flap dissection it is critical to maintain the lowest branch to minimize donor morbidity.

**Sensory**
The ventral primary rami of the mixed seventh through twelfth intercostal nerves provide sensation to the skin territory of the rectus abdominis muscle. In addition, branches from the ilioinguinal (L1) and iliohypogastric (L1) nerves provide additional supply to the lower abdomen. Intercostal branches can be harvested with a free flap (TRAM, VRAM, DIEP) to provide a sensate flap.

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**Fig. 10B-1**  
D, Longitudinal cross-section of chest and abdomen showing the varied sources of blood supply to the rectus abdominis muscle and its perforators.  
E, Upper abdominal cross-section demonstrating the interconnection of the superior epigastric and lateral intercostal systems.  
**Dominant pedicles:** Superior epigastric artery; deep inferior epigastric artery
Vascular Anatomy
The superior epigastric artery may split into several branches or remain single. The superior epigastric vessel supplies the proximally based pedicled transposition flaps. The deep inferior system supplies free TRAM or inferiorly pedicled rectus flaps.

The superior and deep inferior systems communicate in the periumbilical area through a system of choke vessels. Taylor has described these in detail. The superior and inferior epigastric vessels often mirror their flow patterns. A single vessel is present in 29% of cases, a dual system occurs in 60% of cases, and the remainder exist as multiple smaller branches, all of the above communicating through a choke system.

Fig. 10B-2 Anatomic variations in epigastric circulation choke vessels within the rectus muscle.
**Vascular Anatomy of the Rectus Abdominis and TRAM/DIEP Flaps**

**Fig. 10B-3**

**Dominant pedicles:** Superior epigastric artery ($D_1$) and inferior epigastric artery ($D_2$)
- $e$, Superficial inferior epigastric artery
- $m$, Myocutaneous perforating vessels from deep epigastric artery
- $p$, Pubis
- $s$, Segmental subcostal arteries
- $u$, Umbilicus
- $x$, Xiphoid process

Resin injection of epigastric vessels supplying the rectus abdominis muscle

Radiographic view

Vascular injection of anterior abdominal wall

Elevation of abdominal skin showing lateral row perforators from DIEA
TRAM Zones

When a lower or midabdominal flap is harvested (a TRAM flap), the blood supply will vary, depending on the location of the tissue relative to the rectus muscle. The best blood supply will directly overlie the rectus muscle (zone I), as this is where the perforators enter the skin island. The areas over the contralateral rectus (zone II) and just lateral to the rectus (zone III) are in the neighboring angiosome and have the next-best blood supply; these vary from patient to patient. The tissue lateral to the contralateral rectus is a tertiary angiosome and usually is the least perfused tissue in the flap.
FLAP HARVEST

Design and Markings
The flap may be designed as a muscle flap alone or with a vertically oriented skin island (VRAM), a transversely oriented skin island (TRAM), or a thoracoepigastric design. The transversely oriented island typically extends from just above the umbilicus to the pubic crease. Moving the design more superiorly improves blood supply (midabdominal TRAM) at the cost of a more noticeable scar. The vertical skin island can extend from the costal margin to the pubic crease. By including an extension superiorly and obliquely above the umbilicus (thoracoepigastric flap), even more tissue can be harvested, with primary closure of the donor site. This design takes advantage of the communication between the intercostal and epigastric systems. Zones I through IV designate the relationship of the skin island to the rectus muscle flap.

Vertical (VRAM)
The skin island is designed as a tapering ellipse oriented vertically along the long axis of the rectus muscle. The island may extend from costal margin to just above the pubic skin crease. The width of the skin island is determined when the patient is supine, the tissues can be pinched to determine how much tissue can be harvested while still allowing primary donor site closure. The medial incision should remain in the midline to preserve the blood supply to the umbilicus. The patient should be warned that the umbilicus will be pulled to the side of harvest.

Vertical skin island design

Fig. 10B-5
**Abdomen**

10B: Rectus Abdominis and TRAM/DIEP Flaps

**Transverse (TRAM)**
The skin island extends from just above the umbilicus centrally to the pubic crease, tapering as a horizontal ellipse laterally to end over the iliac crest, lateral to the anterior superior iliac spine. Markings for a pedicled TRAM flap are identical to those of the free TRAM and DIEP flaps. If more rectus perforators are desired within the flap, the skin island can be moved up to capture more periumbilical and superior epigastric perforators (midabdominal TRAM).

![Fig. 10B-6](image1)

Transverse inferior skin island design

**Thoracoepigastric**
Initially, the VRAM design is designed inferiorly, then an elliptical extension is designed along an imaginary line from umbilicus to the costal margin at the anterior axillary line, again pinching the tissues to ensure primary closure of the donor site.

![Fig. 10B-7](image2)

Transverse superior skin island design
Patient Positioning
Patients are placed supine on the operating table regardless of the type of rectus-based flap to be harvested. Before the patient is prepared and draped, the operating table must be tested to ensure that it can flex at the patient’s waist to facilitate closure in TRAM and DIEP flap procedures. Failure to achieve flexion intraoperatively may seriously compromise the surgeon’s ability to close the abdominal donor site without tension. A pillow placed beneath the knees to allow slight hip flexion can also be helpful during closure.

GUIDE TO RECTUS MUSCLE–ONLY FLAP DISSECTION
Because no skin island is required in the purely muscular version of the rectus flap, the abdominal skin is incised as a vertical paramedian incision and dissection is carried straight down to the anterior rectus sheath. Skin should not be undermined off the rectus sheath to preserve cutaneous blood supply. The anterior rectus sheath is incised vertically and dissected off the anterior aspect of the muscle belly from the costal margin as far inferiorly as required. Dissection is carried laterally to the linea semilunaris and medially to the linea alba. Care should be exercised when dissecting over the tendinous inscriptions, because the epigastric vessels are quite superficial within the insertion and can be damaged. Laterally all intercostal neurovascular bundles should be divided with either cautery or sharply between hemostatic clips to control bleeding. The eighth intercostal nerve at the costal margin should be sought and divided specifically to prevent muscle contraction in a proximally based flap. If a superiorly based flap is to be raised, the deep inferior epigastric vessels should be clamped and divided, following which the distal muscle belly, or preferably the tendinous origin, is then divided with cautery.

The flap is then rotated superiority to cover a chest or upper abdominal defect. If a distally based muscle is raised, the proximal muscle is divided at the costal margin taking care to secure control of the superior epigastric pedicle as it emerges from beneath the rib margin. The muscle can then be rotated down into the pelvis or groin as needed.

Fig. 10B-8  A and B, Superiorly based pedicle before and after dissection.
**FLAP VARIANTS**

- Myocutaneous flap
  - Vertical rectus abdominis myocutaneous (VRAM) flap
  - Thoracoepigastric flap
  - Transverse rectus abdominis myocutaneous (TRAM) flap
    - Unipedicle
    - Bipedicle
  - Midabdominal TRAM flap
- Free TRAM (full muscle/muscle-sparing) flap
- Deep inferior epigastric perforator (DIEP) flap
Pedicled Vertical Rectus Abdominis Myocutaneous (VRAM) Flap

If a skin island is incorporated, the skin island is planned in accordance with the markings mentioned earlier. The skin island is incised as a long vertical ellipse tapering proximally and distally. Dissection is carried down initially to the abdominal fascia. Laterally a subcutaneous plane is maintained until the semilunar line is reached. Medially, the incision is carried down directly to the linea alba. The rectus sheath is incised and the muscle is then dissected out from within the sheath laterally and medially as described in the previous section. The anterior rectus fascia may be spared to the level of the lateral row perforators to aid the fascial closure (lateral fascia sparing). Great care should be taken to preserve the relationship between the muscle, its fascia, and overlying skin island to preserve the perforator blood supply to the skin.

For pelvic and vaginal reconstruction, the VRAM is an ideal flap, because it can supply a large amount of tissue with a favorable arc of rotation transabdominally. Pelvic dead space is also obliterated and herniation formation prevented. In these cases, the pubic fascial insertion is maintained to protect sheer of the pedicle postoperatively.
Thoracoepigastric Flap
When additional tissue is required behind the VRAM for inferiorly based flaps, a thoracoepigastric flap can be considered (see Section 10F). This design takes into account the anastomosis between the intercostal and epigastric systems. The extension of the flap is centered above the line from the umbilicus to the shoulder. The flap can be extended to the midaxillary line. Dissection starts superiorly and laterally first in the subcutaneous plane until the semilunar line is reached. Dissection then proceeds as described for the inferiorly based VRAM.

Pedicled Transverse Rectus Abdominis Myocutaneous (TRAM) Flap
The upper abdominal incision is made first and dissection is carried down to the rectus sheath. The upper abdominal skin flap is elevated over the costal margins laterally and to the xiphoid centrally. The patient is flexed to assess the adequacy of skin closure to the inferior incision line. The inferior incision may need to be moved superiorly to allow for a less tight abdominal skin closure. Tight closure can seriously compromise blood flow to the skin edges, causing skin necrosis, particularly in the area between the umbilicus and pubis, especially in obese patients. Preexisting Pfannenstiel incisions can be ignored, because they do not affect the survival of suprapubic skin. The distal incision is then made, and the TRAM flap is elevated from lateral to medial, to the lateral row of perforators passing through the rectus
abdominis muscle. The decision about which side to base the flap depends on abdominal anatomy size, the prevalence of perforators, and surgeon preference. A conventional open cholecystectomy scar (Kocher incision) mandates a left-sided unipedicled flap, because the approach has divided the superior epigastric system. Laparoscopic incisions and midline incisions are rarely a cause for concern unless they perforate the rectus muscle close to the superior pedicle. Appendectomy scars can be problematic and may require inspection of the fascia during surgery.

![Fig. 10B-11](image)

**Fig. 10B-11** A, A skin-sparing mastectomy has been performed. The upper TRAM incision has been deepened to the fascia. B, The umbilicus is circumferentially freed. C, The flap is elevated from lateral to medial with identification of the lateral row perforators just medial to the semilunar line. D, The row of lateral perforators is exposed. The lateral fascia is opened, and the muscle is dissected directly. E, After division of the pubic insertion and the DIEA and DIEV vessels, the hemiflap is transposed to the chest through a tunnel connecting the abdominal donor to the chest recipient.
In an unscarred abdomen either the contralateral or the ipsilateral pedicle may be used (see Fig. 10B-11). An ipsilateral transfer eliminates the problem of initial intermammary bulging and the definition of the ipsilateral inframammary crease is excellent. Pedicle tension is reduced and flap positioning tends to be easier. Venous drainage is better with ipsilateral transfer. The contralateral pedicle tends to create more medial inframammary crease bulging and somewhat limits the ease of flap positioning in terms of more lateral motion.

**Fig. 10B-11**  
F, The ipsilateral pedicle on the left rotates 90 to 180 degrees counterclockwise. A similar flap based on the right would rotate clockwise.  
G, The contralateral flap based on the right rotates 90 to 180 degrees counterclockwise. A similar flap based on the left would rotate clockwise.
The muscle can be elevated in its entirety or with a muscle-sparing technique. Muscle-sparing involves identifying the intramuscular course of the superior epigastric vessels with a Doppler probe and then leaving a lateral strip of muscle some 2 cm in diameter. Theoretically, this leaves muscle innervated and vascularized by the intercostal vessels and nerves for further abdominal wall competence postoperatively. In practice, however, the intercostal supply penetrates the rectus muscle in its middle third, thereby leaving no innervation and probably little, if any, blood supply to the lateral muscle strip. A medial strip of muscle may also be left, but its functional value is questionable. As noted earlier, Harris demonstrated an 80% reduction in pedicled blood flow by clamping the medial and lateral thirds of the rectus muscle intraoperatively. Recent data on the diminishing size and strength of residual upper rectus muscle after free TRAM flap harvest further call into question the validity of performing muscle-sparing procedures. The rectus muscle is divided distally and the deep inferior epigastric vessels are ligated with surgical clips. These vessels should be dissected out with the flap just in case they are needed for conversion to a free flap or supercharging in the event of vascular compromise of a pedicled flap.

**Fig. 10B-11**

Harvest of muscle-sparing TRAM flap

Medial and lateral margins of rectus muscle remain intact

Medial and lateral margins of rectus muscle remain intact
For chest and breast applications, flap elevation is based on the superior epigastric supply. Care should be taken to divide the eighth intercostal nerve as it enters the muscle near the costal margin. The nerve is often under the muscle and should be located and divided. This essential maneuver facilitates muscle atrophy, reducing epigastric bulk in the long term and eliminates the need for considering the issue of muscle sparing as a means of reducing pedicle bulk at the costal margin.

**Bipedicle TRAM Flap**

The bipedicle TRAM flap is indicated in:

- Large-volume reconstruction
- Patients with lower midline abdominal incisions
- Patients who smoke
- Obese patients
- Patients with radiation injury to one pedicle
- Bilateral unipedicle breast reconstruction

Most of the above represent indications for free TRAM flap transfer in many surgeons’ hands. Bipedicle flaps are robust and probably have a better blood supply than free TRAM flaps because of the conversion of zones II and IV to additional zones I and III respectively. They allow for more reliable survival of a greater proportion of the flap at the expense of greater abdominal donor site muscle loss. While this affects the patient’s abdominal strength in the short term, longer term function appears eminently compatible with activities of daily living. Flap complications are less and the procedure enables the nonmicrosurgeon to safely perform TRAM flap breast reconstruction in higher risk patients.

Preoperative preparation and positioning are similar to those outlined for the unipedicled procedure. Initial flap elevation is identical in that both sides of the flap are dissected to the lateral perforators. Medial dissection differs in that a tunnel must be fashioned down the linea alba between the two pedicles. This leaves a fascial strip on either side of the linea for fascial closure, because two pedicles have to pass up onto the chest wall, a more generous tunnel has to be fashioned, causing more initial bulging; patients should be informed about this preoperatively.
Fig. 10B-12  A, Operative plan for a bipedicle flap. B, Bipedicle flap showing the relationship of midline tunnel to the muscle attachments. C, Cross section illustrating the relationship of two muscle pedicles to the overlying skin island and umbilicus. D, Flap donor site showing a rectus sheath defect. E, Mesh closure of a bipedicle donor site.
Midabdominal TRAM Flap
In some patients, the lower abdominal pannus is unusable because of size, edema, or previous surgery. The midabdominal TRAM is an excellent alternative, because it takes advantage of abdominal excess but avoids the risks of poor blood supply resulting from morbid obesity and previous surgery. In fact, by moving the design superiorly, the blood supply becomes a primary angiosome and is improved. The downside is a midabdominal scar. In the patients described here, this is often not objectionable.

Although the pedicle may seem short, an ipsilateral flap reaches the chest easily. Dissection of the flap begins with deepening of incisions to fascia and elevation of the flap from lateral to medial. The dissection is then similar to a pedicle TRAM, except the muscle is divided at the level of the umbilicus. If deep inferior epigastric branches are encountered, they are ligated. Unlike the lower abdominal TRAM, there is less cross-circulation and tissue for the reconstruction should be mainly from zones I and III.

Free TRAM Flap
Of all free flaps used in breast reconstruction, the free TRAM flap is by far the most commonly used, followed by the DIEP flap. The flap has a pedicle of adequate length with a large vessel lumen diameter. Although a small portion of the infraumbilical part of the rectus muscle and anterior rectus sheath must be sacrificed, it is negligible compared to the amount that must be sacrificed with the standard superior pedicle TRAM flap.

Free TRAM Flap Variants
- MS-0: No muscle sparing, using the full width of the rectus muscle
- MS-1: Lateral muscle strip preserved
- MS-2: Lateral and medial muscle strip preserved
The patient is positioned supine on the operating table with both upper extremities abducted to 90 degrees on arm boards. The arm on the breast reconstruction side is draped to allow access to axillary vessels as well as to the internal mammary supply for the microsurgical transfer.

The TRAM flap skin island is marked on the abdomen similar to the markings for a standard pedicled TRAM flap. The incision on the chest wall will vary according to local conditions and scars. In a delayed reconstruction, the previous scars are excised, the mastectomy flaps are raised, and the appropriate recipient vessels are explored. In skin-sparing mastectomies, this component of the dissection has already been completed.

The incisions are made and the skin island elevated as for the standard unipedicle TRAM flap. It is worth preserving the superficial inferior epigastric veins for additional venous drainage if required. These can be dissected for a length of 5 to 6 cm inferiorly to provide length and can provide additional venous outflow to the flap. Unfortunately, these veins are not always present or usable.

If the internal mammary vessels are used, the flap may be based on the ipsilateral DIEA axis, because this allows a 180-degree rotation, which keeps the pedicle and zone I medial and the periumbilical fullness inferior to mimic the natural lower pole of a normal breast. If the thoracodorsal vessels are used, the contralateral pedicle is best used, the only disadvantage being that zone II is now medial, and this has a slightly less predictable blood flow. Unlike a pedicle TRAM flap, tethered by its pedicle, a free TRAM or DIEP flap can be based on either contralateral or ipsilateral pedicles and freely inset.

The skin island is elevated to the lateral and medial perforator rows. The deep inferior epigastric vessels are identified at the inferolateral border of the distal rectus abdominis muscle. Under loupe magnification, the vessels are dissected free from the surrounding tissues and traced down to the iliofemoral junction.
A pedicle of 8 to 10 cm in length can then be dissected easily. The accompanying veins usually converge to become a single large-caliber vena comitans before entering the iliofemoral junction or external iliac vein. Generally, the flap contains one artery and two venae comitantes.

**Fig. 10B-14**

**Deep Inferior Epigastric Perforator (DIEP) Flap**

The DIEA or perforator flap was conceptualized in an effort to reduce abdominal donor site morbidity while maintaining the improved blood flow associated with the free TRAM flap. The flap incorporates the same skin elements as the TRAM flap but relies on dissecting the perforating blood vessels through the rectus muscle, thereby leaving all of the rectus muscle behind at the donor site and removing only the flap with its vascular pedicle. These perforating vessels are clustered in two rows in the periumbilical area, with medial perforators being most numerous and commonly used as the basis of the DIEP flap.
Flap markings for the DIEP flap are similar to those for the standard TRAM flap, although care should be taken to place the bulk of the flap over the perforators. This may require harvesting more ipsilateral tissue laterally and discarding the contralateral zone IV completely as well as part or all of zone II.

**DIEP Flap Elevation**

The DIEP skin flap is elevated in a manner similar to the conventional free TRAM flap. Every effort should be made to harvest the superficial inferior epigastric vein with the flap to maximize venous outflow options. This vessel should be dissected distally to the femoral vein to obtain as much length as possible. Dissection is carried from lateral to medial to the lateral row of perforators. If preoperative Doppler or spiral CT localization of the best perforator has been performed, dissection is carried out to that vessel. The use of indocyanine green (ICG) laser angiography is immensely helpful in localizing these perforators. Immediately lateral to the desired perforator, the rectus sheath is opened longitudinally and the lateral border of the rectus muscle is exposed and reflected medially to identify the deep inferior epigastric vessels. These are traced through the rectus muscle following the major cutaneous perforator into the skin island. During this dissection, it is imperative that all intramuscular nerve branches be preserved to maintain the innervation of the abdominal wall muscles. No muscle is removed, thereby optimizing the strength of the abdominal wall. Following flap harvest, the sheath is closed in linear fashion.

**Fig. 10B-16**  
**ARC OF ROTATION**

**Pedicled TRAM/Rectus Flaps**
The pedicled rectus, VRAM, or TRAM flaps can reach the upper manubrium superiorly as proximally based flaps, as well as almost any area on the anterior chest. The inferiorly based muscle and VRAM flaps can cover proximal thigh and groin defects, as well as the pelvis, vagina, and perineum centrally.

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**STANDARD FLAP**

![Diagram of Arcs to Various Areas](image)

**Thoracoepigastric Flap**
The thoracoepigastric extension will extend the reach of an inferiorly based (deep inferior epigastric supply) by the length of the thoracoepigastric extension. A folded sterile towel can be used intraoperatively to simulate flap reach.
FLAP TRANSFER

Muscle-Only Flap

For a chest application, a gap in the fascial closure is necessary to allow the passage of the muscle. This defect is best tolerated in a subxiphoid position and is worst tolerated in the suprapubic position. Transdiaphragmatic passage allows complete primary fascial closure. For groin defects, passage of the flap below the inguinal ligament avoids this issue, but division of the inguinal ligament is sometimes required. If the inguinal ligament is divided for flap passage, it must be repaired before skin closure.

Pedicled TRAM (Unipedicle, Bipedicle, Midabdominal, Superiorly Based VRAM) Flap

A gap in the fascial closure is necessary to allow passage of the flap to the chest, avoiding too tight a fascial closure, which can compromise blood flow in the pedicle. Two fingers should easily pass alongside the pedicle at the fascial opening to avoid this problem.

For chest wall applications, the flap can be directly placed into the defect by incising the connecting skin, thus avoiding compression of the pedicle in a tunnel. For breast reconstruction, a wide subcutaneous tunnel is made between the abdominal dissection and the recipient site allowing passage of the pedicle without compression. When using a contralateral pedicle it is tunneled adjacent to the medial border of the normal breast. Ipsilateral flaps are passed straight up through the inframammary fold of the mastectomy site. If venous congestion occurs, repositioning may be helpful. Additionally, one may remove the surgical clip on the deep inferior epigastric vein stump and allow it to bleed for several minutes for venous decompression. Gradually the venous flow in the flap adjusts to the new flap location and drainage direction, and the flap assumes a healthier color. Alternatively, Hartrampf’s “mechanical leech” drainage system may be inserted into the deep inferior vascular system to aid in venous decompression. This involves inserting a pediatric feeding tube or venous cannula into the deep inferior epigastric vein and using this as a decompression valve that can be opened periodically to bleed the flap of congested, poorly oxygenated venous blood under pressure. It mandates that the surgeon harvest a usable stump of deep inferior epigastric vein at the time of TRAM flap harvest. The catheter can be flushed with dilute heparin solution to maintain its patency over a period of 2 or 3 days as needed. Alternatively, the distal cut end of the deep inferior epigastric vein may be anastomosed to an appropriate adjacent vessel such as the internal mammary or an intercostal perforating vein to provide adequate venous outflow.

Fig. 10B-18  A, The subcutaneous tunnel viewed from below showing a retractor in the mastectomy site passed through the tunnel. B, The surgeon’s hand placed from the abdominal incision into the mastectomy site.
VRAM (Inferiorly Based) Flap
Passage of the flap for groin and thigh defects is similar to the muscle-only flap above. When used for vaginal reconstruction, abdominoperineal resection defects, or pelvic reconstruction, the flap is transferred through the open abdomen, through the presacral space to the perineum. Care is taken to ensure no torsion or kinking of the pedicle; this is best done through the lithotomy approach, where the pelvic defect outside and the pelvic inlet inside can be visualized simultaneously. The flap is first passed through the tunnel and marked for skin resection while temporarily in place. The flap can then be passed back through the abdomen, where deepithelialization and debulking can be performed under direct vision. The flap is then passed back to the recipient site for inset. The fascial insertion of the muscle to the pubis is maintained to prevent postoperative tension and ischemia but can be released if additional length is required.

FLAP INSET
Pedicled Flap
Tension-free closure is the goal for all variants of the pedicled rectus flap. Fascia carried with the flap is useful for anchoring the flap at its recipient site, taking tension off the pedicle and the skin closure. Areas of potential ischemia, such as TRAM zone IV and areas of the VRAM/thoracoepigastric region not directly over muscle, should be inspected carefully before inset. Poor vascularity should be managed by resection or delay of inset.

Free Rectus Flap
When the rectus muscle, with or without a skin paddle, is used for reconstruction, care must be taken to secure the muscle to the surrounding bed to allow a tension-free microanastomosis.

Free TRAM Flap
With the flap isolated and ready for transfer and the recipient vessels isolated, the microscope is then brought into the operating field for final vessel preparation. The site is prepared under microscopic magnification, the flap and deep epigastric artery and vein are divided, and the vessel ends are irrigated with heparinized saline solution. The flap is then transferred to the chest wall, where it is temporarily secured with sutures or staples. At this point the pedicle length may need to be adjusted, particularly when using a TRAM flap that has a very long pedicle that may need to be shortened, depending on the local conditions, before end-to-side or end-to-end vascular anastomosis is performed.

If the vessels sizes are a good match, an end-to-end anastomosis is appropriate. However, if there is any size discrepancy between the flap vessel and the recipient vein (the flap vessels usually being larger), an end-to-side anastomosis should be performed. This allows the Venturi effect to siphon venous flow out of the flap, encouraging drainage. If end-to-end anastomoses are performed on the vein, the use of the vein coupler saves time. If the superficial inferior vessels are harvested with the flap or a second vena comitans is present, they can be anastomosed as retrograde flow vessels to the distal ends of the internal mammary vessels.

At this stage, the overlying skin island may be turned and modified as necessary to inset the flap. The TRAM flap is then shaped and inset. If the internal mammary vessels are used, the flap is oriented transversely or obliquely, with zone I medially and zone III laterally. If the thoracodorsal vessels are used, the free TRAM flap has an inferior pedicle directed toward the axilla, it is usually inset transversely or obliquely, with its pedicle directed laterally. Zone I is usually placed along the lateral portion of the breast and zone II on the
medial portion of the breast, particularly when the flap is inset in a transverse direction. Zone III is used for axillary fill and can provide additional fullness to match the volume of the opposite breast. The free TRAM flap is deepithelialized as necessary and definitively inset over suction drains. The shaping and insetting of the TRAM flap proceed as described for standard flap reconstruction.

**DONOR SITE CLOSURE**

All pedicle flaps that have suprafascial recipient sites must, by definition, leave a fascial defect to allow muscle pedicle transfer. In the TRAM and superiorly based VRAM flaps, this defect in the xiphoid area is well tolerated. One should avoid such defects in the suprapubic area in an ambulatory patient, because a hernia may form. Transabdominal passage and opening the inguinal ligament are two alternatives that can be used in selected cases.

The muscle is enclosed by the anterior and posterior rectus sheaths. The anterior sheath consists of the blended aponeuroses of external and internal oblique muscles; the posterior sheath is composed of the blended aponeuroses of the internal oblique and transversus abdominis muscles. At the arcuate line and inferiorly, the internal oblique contributions to the posterior sheath run anteriorly, so the anterior sheath dominates and the posterior sheath is diminutive.

Abdominal closure should not be relegated to the most junior member of the team, because poor closure dramatically increases the risks of hernia formation. It is essential to incorporate both the internal and external oblique aponeuroses into the sheath closure. If fraying of the fascia occurs it can be darned with a suture weave or covered with an onlay of synthetic mesh or acellular dermal matrix. In a bipedicle TRAM, the surgeon should have a low threshold for using mesh for fascial closure. Once the abdominal fascia has been securely closed, the upper abdominal skin flap is redraped over suction drains and closed. An umbilicoplasty is then performed.

**Fig. 10B-19**

Direct fascial closure with Prolene mesh inlay

Closure
Free TRAM Flap

The muscle-sparing type II (MS-2) free TRAM flap harvest leaves a small rectangular defect in the rectus muscle belly. This can be repaired directly with running 2-0 PDS or Vicryl, and the rectus sheath is repaired with 0 Prolene. If there is any concern about tension or fascial strength, a sheet of Prolene mesh or acellular dermal matrix can be placed to buttress the repair. Final closure then proceeds as described above.
CLINICAL APPLICATIONS
This 46-year-old woman was diagnosed with right breast cancer and was interested in immediate free TRAM flap or DIEP flap breast reconstruction to optimize abdominal wall strength. She was a healthy nonsmoker with mild preoperative breast asymmetry, the left side being lower than the right. She preferred the appearance of the left breast and requested symmetry with this side to negate any mastopexy scarring on the left. A muscle-sparing type II (MS–2) free TRAM flap was performed, because the perforating vessels were extremely small and unsuitable for a DIEP flap. Anastomosis was performed to the right thoracodorsal vessels through the sentinel node biopsy site in the right axilla. Subsequently, a right nipple reconstruction was performed using a C–V flap technique.

![Fig. 10B-21](image)

A, Preoperative right breast cancer. Note that the right breast is higher than the left. B, Muscle-sparing flap harvest. C, Muscle-sparing type II (MS-2) free TRAM flap.
**Fig. 10B-21**  
D, Muscle-sparing free TRAM donor site before closure. E, Donor site closure. F and G, AP and oblique views of postoperative result 1 year after surgery demonstrating excellent shape and symmetry; the right breast is at the same level as the left breast. (Case supplied by GJ.)
This 55-year-old woman was referred for left breast reconstruction. She had undergone a left mastectomy, followed by chemotherapy and radiation. Her course was complicated by a recurrent seroma with wound breakdown at the mastectomy site after completion of radiation therapy. Dressing therapy coupled with hyperbaric oxygen treatment was necessary; the wound took 9 months to heal. She had a 40-pack-year history of smoking and stopped smoking before her reconstruction. She had had a left paramedian incision 20 years previously for ovarian surgery. Fifteen months after her mastectomy, a muscle-sparing free TRAM flap was planned because of her history of smoking and radiation therapy. It was thought that unless her vascular anatomy was exceptional, a DIEP flap would be risky in this former heavy smoker. At operation, vascular imaging with laser-induced indocyanine green fluorescence was performed, demonstrating a surprisingly large perforator bloom just below and lateral to the right of the umbilicus. Intraoperative exploration confirmed the presence of a very large (2 mm) perforator supplying a large portion of the right side of her abdominal pannus. A DIEP flap was harvested based on this perforator, with anastomosis to the left internal mammary vessels. After uneventful flap healing, a contralateral right vertical breast reduction was performed, together with left nipple reconstruction using a C-V flap. She is shown 1 year postoperatively with good symmetry and a soft, supple breast reconstruction.

Fig. 10B-22  A, Preoperative view showing paramedian scar and irradiated mastectomy. B, Intraoperative planning.
Fig. 10B-22  C, Large 2 mm DIEA perforator on right side. D, Nerve-sparing dissection. E, DIEP flap harvested with two perforators. F, Donor site before closure. G, Healed left DIEP flap. H, Final result 1 year after right breast reduction and left nipple reconstruction. (Case supplied by GJ.)
This 58-year-old woman was diagnosed with right breast cancer. She had bilateral mammary hypertrophy and a well-developed lower abdominal pannus. She did not exercise regularly and was a nonsmoker. The surgical plan involved an immediate right ipsilateral, unipedicled TRAM flap breast reconstruction, with subsequent contralateral vertical breast reduction and right nipple reconstruction. An oblique orientation of her TRAM flap skin island achieved a natural breast shape with good infraclavicular fill with maintenance of the anterior axillary fold. Two months after her initial reconstruction, she underwent contralateral left breast reduction using a vertical technique, coupled with a C-V flap right nipple reconstruction and tattooing of the areolas. Shape and symmetry are excellent and the abdominal contour is pleasing.

**Fig. 10B-23**  
A, Preoperative right breast cancer. Note well-developed lower abdominal pannus.  
B, Planned flap orientation.  
C, Early postoperative result with right ipsilateral unipedicled TRAM flap.  
D, Final result after right pedicled TRAM flap and contralateral vertical breast reduction for symmetry.  
(Case supplied by G.J.)
This 68-year-old woman had undergone a left radical mastectomy and radiation 26 years before presenting with severe osteoradionecrosis of the chest wall. Necrosis had resulted in exposure of the pericardium, pleura, and multiple costal cartilages. Episodes of hemorrhage from the internal mammary vessels were occurring more and more frequently. Treatment required a life-threatening massive chest wall resection, including the left anterior chest wall, entire sternum, and some right costal cartilages. Both internal mammary vessels were resected to their origin. A large free TRAM flap based on the left deep inferior epigastric vessels was anastomosed to the origin of the right internal mammary vessels from the great vessels. Complete coverage and stable healing was achieved. Because of the radiation-induced stiffness of the underlying pleura and lung, no attempt was made to place Gore-Tex or methylmethacrylate-impregnated mesh to reinforce the chest wall reconstruction. The patient was last seen 6 years after surgery and remained well healed and functional.

Fig. 10B-24  A, Irradiated chest wall after a radical mastectomy and osteoradionecrosis. B, Radical resection of the left anterior chest, sternum, and right costal cartilages. Both internal mammary arteries were resected and the heart and both lungs were exposed. A free TRAM flap was incised. C, One-year postoperative result showing a healed free TRAM flap with anastomosis end-to-side with the great vessels. (Case supplied by G.J.)
This 42-year-old woman had a history of left breast cancer and chest wall irradiation and desired breast reconstruction. She had macromastia on the right and wanted reduction. She also was obese and had a previous Kocher incision from a previous open cholecystectomy. She had adequate tissue for reconstruction in both her lower abdominal pannus and her midabdominal pannus. Normally a large subcostal scar such as hers could pose an ischemic problem for any lower abdominal TRAM, because the tissue left between the two long scars would be ischemic. A midabdominal TRAM was chosen to allow successful reconstruction and to limit abdominal wall ischemia. A contralateral breast reduction was also performed at the initial procedure.

Fig. 10B-25  A, Preoperative markings show her planned breast reduction and the location of the TRAM relative to her subcostal scar. Since the design abuts the scar, no intervening areas of ischemia were created at the donor site. The midabdominal scar created by a higher flap design did not concern the patient. An ipsilateral pedicle was used for the rotational flap, because it avoided the areas of previous surgery and the likely transection of the superior epigastric vessels on the right. The patient had a superomedial pedicle breast reduction in which 925 g of tissue was removed.  B, The patient is seen at her 1½-year follow-up; during that postoperative period one bilateral revision was performed, with liposuction and scar revisions. A nipple share for nipple reconstruction is pictured after completing her tattoo in the office.  C, Right oblique and  D, left oblique views. (Case supplied by MRZ.)
This 35-year-old man had a recurrent angiosarcoma of the right hip. He had previously undergone resection, chemotherapy, and radiation therapy. He presented with recurrence and bleeding.

**Fig. 10B-26**  
A, Proposed skin resection to remove all previous scars and provide access for resection.  
B, Wound after resection of full-thickness abdominal wall, ASIS of pelvis, inguinal lymph nodes, and surrounding soft tissue. Note previous midline incision.  
C, Abdominal hernia repaired with mesh. Proposed VRAM based on contralateral deep inferior epigastric vessels. Abdominal tissues are a better choice than local thigh tissue because of previous radiation damage and the need to add tissue to the area.  
D, After flap elevation and inset. Flap pedicle was passed above the mesh repair. Sometimes the flap can be passed below the fascia, simplifying abdominal wall closure. Some primary closure of the thigh was performed, and primary donor site closure was achieved. (Case supplied by MRZ.)
This 73-year-old woman had recurrent breast cancer despite chemotherapy and chest wall irradiation. She had a large chest wall resection, and a VRAM flap was planned for closure. The VRAM flap provides more soft tissue than the latissimus or external oblique muscles. The vertical design is favored over the transverse design (TRAM) to provide the best possible blood supply to all parts of the flap.

**Fig. 10B-27**  
A, Large chest wall resection requiring only soft tissue coverage. A contralateral VRAM was planned. The size of the flap was based on what could be harvested and closed primarily, not on the defect size. If more tissue was required, a second flap could be added. B, Flap inset and donor site closed primarily. Like most pedicle TRAM flaps, some congestion is noted at the inset. One can supercharge the deep or superficial inferior epigastric veins, if indicated. C, The patient is seen 6 weeks postoperatively (AP view). She healed uneventfully. No venous supercharge was performed. D, Oblique view. (Case supplied by MRZ.)
This 66-year-old patient had recurrent melanoma of the left leg and presented with bulky adenopathy of the left groin involving the femoral artery and its tributaries.

Fig. 10B-28  A, The surgical defect is seen after removal of the tumor and reconstruction of the femoral vessels with a Gore-Tex graft. An old skin graft donor site is seen inferior to the wound from his original melanoma surgery. The proposed VRAM is shown. Because of the sacrifice of the femoral vessels and its tributaries, local flaps were excluded and the VRAM on a contralateral pedicle was chosen.  
B, The abdominal wall defect was repaired with mesh, leaving a space for the femoral vessels and the VRAM pedicle. The flap is seen before final inset; the mesh can be seen superior to the flap.  
C, The flap was inset and the lateral portion of the wound away from the Gore-Tex graft was skin grafted. The donor site was closed primarily.  
D, The patient is seen 2 months postoperatively after healing uneventfully. (Case supplied by MRZ.)
This 58-year-old woman had undergone abdominoperineal resection for advanced Crohn’s disease. The surgery created a permanent colostomy, and the rectum and associated posterior vaginal wall were removed. This is a common defect after abdominoperineal reconstruction for cancer. The VRAM can be harvested while the abdominal portion of the operation is being performed and is passed through the abdomen and pelvis to the perineum, where it can be used for reconstruction.

Fig. 10B-29  A, The surgical defect after removal of rectum, posterior vagina, and surrounding perineal skin. The lap pad is seen in the presacral dead space left by the removal of tissues. B, The VRAM after inset into the perineal defect. Skin of the flap is used to resurface the perineum where the anus once was. C, VRAM skin is also used to recreate the vaginal vault, restoring its posterior wall. The flap, when used in this transabdominal fashion, is helpful in obliterating pelvic dead space and limiting seroma formation. (Case supplied by MRZ.)
This 59-year-old woman had a history of diabetes and prior rectal cancer that had necessitated a permanent colostomy. She was diagnosed with a right breast cancer requiring mastectomy and desired immediate reconstruction with a TRAM flap. She had macromastia and requested reduction of the normal left breast. Because of her colostomy in the left lower quadrant, a standard pedicle TRAM reconstruction was not possible. However, she did have ample tissue available in the midabdomen and was offered a midabdominal TRAM breast reconstruction.

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Fig. 10B-30  
A, Preoperative view of the patient with macromastia and a colostomy. B, Lateral preoperative view with markings for the midabdominal TRAM and inferior pedicle breast reduction, to be performed concurrently. C, The patient is shown 9 months postoperatively. She required no revisions; a nipple share and tattoo were performed for nipple reconstruction. Note the midabdominal scar, which did not concern this patient. In contrast to a standard TRAM flap, very little lower abdominal undermining is required in such a case for closure. D, Right lateral and E, left lateral views. (Case supplied by MRZ.)
Pearls and Pitfalls

- If the patient has had prior abdominal incisions, there is a risk of previous division of internal muscle circulation or myocutaneous perforating vessels between the muscle and abdominal skin. Any portion of a skin island located beyond the rectus muscle with an intervening old incision will generally not have adequate circulation and should not be included in the skin island design.

- In patients with impaired microcirculation (for example, those with scleroderma or Raynaud’s disease), the skin island should not be extended for excessive distances beyond the primary skin territory of the muscle without a surgical delay.

- Prior use of the internal mammary artery for cardiac revascularization is a relative contraindication for use of a superiorly based rectus muscle flap if alternative techniques are available (such as the opposite rectus muscle). However, the muscle can survive transposition based on musculophrenic and intercostal vessel retrograde flow into the superior epigastric artery.

- Previous major vascular surgery involving the external iliac vessels is a relative contraindication to the use of the inferiorly based rectus muscle or myocutaneous flap, unless selective arteriography confirms the patency of the inferior epigastric artery. Although both superiorly and inferiorly based flaps are commonly used successfully despite prior radiation therapy in proximity to the flap pedicle (such as the mediastinum or groin), an alternative flap is used when available (for example, the opposite rectus muscle flap).

- Prior pelvic surgery, especially through a Pfannenstiel incision, will generally not preclude the use of a transverse skin island on a superiorly based rectus myocutaneous flap. The deep inferior epigastric vessels are rarely violated in gynecologic surgery. However, adhesions between the deep surface of the inferior rectus muscle and pelvic viscera may be present. Preoperative bowel preparation is recommended in the event of colon injury during scar lysis for flap elevation.

- The presence of a subcostal incision over the rectus muscle (Kocher incision for cholecystectomy) is an absolute contraindication to the use of an ipsilateral superiorly based rectus myocutaneous flap. Generally, the contralateral muscle can safely be used as a flap. Circulation to the skin between the subcostal incision and the skin island location may be impaired after donor site closure. A complete bilateral subcostal incision for intraabdominal surgery is an absolute contraindication to use of a superiorly based rectus muscle or myocutaneous flap, because the rectus muscle has been divided, causing loss of integrity of the internal rectus muscle vascular arcade.

- Although segmental flap elevation will preserve the lateral aspect of the rectus muscle, improvement in abdominal function and strength may not be observed. The surgeon must accept the increased risk of injury to the muscle vascular arcade with this technique.

- If closure of the anterior rectus sheath results in tearing of the remaining fascia, the use of a synthetic mesh or acellular dermal matrix replacement of the anterior sheath is recommended. Mesh has the added benefit of avoiding distortion of the midline position of the umbilicus.

- Direct closure of the skin donor site is preferred whenever possible. The use of skin grafts in the donor site results in a significant contour defect.

- When performing a DIEP flap, the surgeon should make every effort to preserve the superficial inferior epigastric vessels as a secondary venous outflow source.
EXPERT COMMENTARY

Michael R. Zenn

Advantages

The rectus abdominis flap is perhaps the most versatile and most used flap in reconstruction. The reasons for this include its dual blood supply, its central location in the body, its convenience, and its duplicity. Dual blood supply is important, because tissue flaps work best when they are rotated toward their blood supply. When basing the flap off the superior epigastric vessels, superior flap rotation allows the possibility of upper trunk and thoracic applications, such as breast and chest wall reconstruction. Even intrathoracic reconstruction is possible. When basing a flap on the deep inferior epigastric system, inferior flap rotation makes lower trunk, groin, and thigh reconstruction possible. Even intraabdominal applications such as pelvic, perineal, and vaginal reconstruction can be done. It is the central location of the muscle and this dual blood supply that allow such versatility.

There is acceptable morbidity from rectus abdominis harvest because of the paired nature of the muscles and maintenance of abdominal wall function that this twofold structure allows. Even in cases of bilateral muscle harvest (such as bilateral breast reconstruction with pedicle TRAM flaps), function is remarkably preserved through the function of the oblique and transversalis muscles.

The rectus abdominis is also an available muscle. Midline scars do not remove the possibility of a vertical rectus abdominis flap. In fact, reconstruction is often required at a time when resection or repair of a problem by other surgical specialties requires a midline incision. Good preoperative planning can allow flap harvest through the same exposure and limit scarring and morbidity to the patient. Communication is essential, because many a potential VRAM flap has been thwarted by a hastily placed ostomy before flap harvest.

Finally, rectus abdominis–based flaps can supply the largest amounts of soft tissue for reconstruction while still allowing primary donor site closure; there are no bony restrictions to closing a vertical donor site, so abdominal circumference can be reduced to allow closure in most patients.

Recommendations

I strongly recommend vertical (VRAM) over transverse (TRAM) flaps for reconstruction when all the tissue is needed for the reconstructive problem at hand. The VRAM flap has a primary angiosome blood supply to the entire flap, whereas the TRAM has a more zonal pattern, with a less predictable angiosomal blood supply. One should not sacrifice a healed wound at the reconstructive site for a nicer scar at the donor site. These cases are hard enough when taking the best possible blood supply, and delayed healing can affect patient survival, especially when adjuvant therapy awaits a healed wound.

Complications

The main complications relating to the use of the rectus flap include ischemia and partial loss, seroma at the donor site, abdominal scar, and loss of functional muscle. When using tissues with the rectus abdominis flap that extend beyond the muscle, tissues may be ischemic, because they represent secondary and tertiary angiosomes. Laser angiography can be helpful for identifying areas of best perfusion so that areas of marginal perfusion can be removed.

Continued
Seroma is common in this area because of the large surface area that is dissected and the mobility of the area. Multiple drains should be used as well as abdominal binders, and the patient’s activity should be limited postoperatively. It is not uncommon for drains to remain in place for 2 to 3 weeks.

It is important to show patients examples of the abdominal scar that they will have after this flap is used. It is surprising to me that even when the donor scar is as nice as an abdominoplasty scar, the patient may still be unhappy with it. There are some cases in which patients have seen photographs of the scar and have requested that another donor site be used. Use of the rectus abdominus muscle and even its perforator variant (DIEP) will affect the function of the abdominal wall. Patients need to be counseled that most individuals do not notice the degree of functional loss postoperatively. The surgeon also needs to discuss the slight possibility of hernias or bulges that may require secondary revision. If the patient is overly concerned about functional loss, an alternative donor site should be sought.

EXPERT COMMENTARY
Glyn Jones

Limitations
Abdominal wall strength is almost certainly more compromised when compared with the unipedicled procedure, and the bipedicle flap should be performed with caution in a younger patient. Problems with backache, early satiety when eating, and constipation may bother some patients. In young women, a free TRAM flap or DIEP flap is probably safer than a bipedicled flap in terms of abdominal morbidity, but this has never been clearly proved.

Personal Experience and Insights
In the Emory review of bipedicled patient results, flap complications and abdominal wall complications were no worse than with unipedicled flaps and flap blood supply was predictably better given the dual blood supply. Our large experience with bilateral and bipedicle flaps has confirmed our initial experience with this procedure as being safe and reliable, with remarkably few complications, considering the higher risk patients in whom it is performed.

Take-Away Messages
Although some surgeons have voiced concern about reduced abdominal strength, this does not appear to be as significant as initially thought, and patients cope remarkably well with activities of daily living. While it is true that strength is initially diminished significantly, particularly in patients’ ability to perform sit-ups, abdominal wall function improves with time, and a remarkable number of patients report little or no negative impact on activities of daily living. Hernia rates are not significantly higher with this procedure when compared with unipedicled TRAM flaps if meticulous abdominal closure is performed with mesh. It is an excellent option for the nonmicrosurgeon who performs large numbers of breast reconstructions in higher risk patients.
**Bibliography With Key Annotations**

**Anatomic/Experimental Studies**


In 65 fresh cadavers the authors performed dye injections, dissections, and barium radiographic studies to delineate the vascular territories of the superior epigastric and deep inferior epigastric vessels. Black ink and red ink were injected into the superior and deep inferior epigastric system and the color changes in the abdominal wall skin were noted. The authors observed that the majority of the abdominal wall was stained through injections of the deep inferior epigastric system. Dissection of the vessels and mapping of the perforators showed that the largest perforating vessels were in the periumbilical area. Barium studies further confirmed the results of the dye study and dissections. The authors concluded that the deep inferior epigastric artery supplies more of the skin of the anterior abdominal wall than the superior epigastric artery. For breast reconstruction the authors stated that prior ligation of the deep inferior epigastric artery would be an advantage when elevating the lower abdominal skin on a superiorly based rectus abdominis myocutaneous flap. They further concluded that flap vascularity would be significantly increased by positioning some part of the skin island over the dense pack of large periumbilical perforating vessels.


In this anatomic and clinical study the authors reviewed 10 angiograms of the internal mammary artery in patients who had undergone previous abdominal surgery, a median sternotomy, or mediastinal irradiation. Twenty cadaver specimens were injected and dissected. In addition to the data gathered from the arteriographic studies and anatomic dissections, the authors drew on their clinical experience with 450 TRAM flaps. They concluded that the internal mammary system and intercostal vessels have a diffuse intrathoracic collateral network with multiple intercommunications on the same side as well as across the midline. Following the interruption of the internal mammary artery, these intercommunications, especially in the intercostal system, assume greater importance and continue to perfuse the internal mammary artery beyond the area of ligation. Despite prior ligation of the internal mammary artery, it is still possible to elevate a superiorly based rectus abdominis flap. Of particular importance is the costomarginal artery running along the costal margin into the rectus abdominis.


The authors studied the vascular anatomy of the rectus abdominis based on the superior epigastric system in 67 fresh cadavers. They described three patterns of anastomosis between the deep superior epigastric artery and the deep inferior epigastric artery. In type I, 29% had a single deep superior epigastric artery and deep inferior epigastric artery. In type II, 57% had a double branch system of each vessel, and in type III, 14% had a system of three or more major branches. In each pattern the two systems intercommunicated through choke vessels. These intercommunications were always located above the level of the umbilicus. The authors also studied the vascular supply to the various transverse and vertical skin islands based on the deep superior epigastric artery. They conclude that the upper transverse and vertical flaps have the best supply and the TRAM flap is the least well vascularized. Midline crossover was seen most often in the subdermal plexus and on the surface of the rectus sheath. Based on these anatomic findings, the authors recommend harvesting the entire width of the muscle and including some of the anterior rectus sheath for muscle harvest to enhance the circulation to the transverse island.
Clinical Series

General

The authors described their technique for harvesting the TRAM flap and specifically the closure of the abdominal wall with mesh. This technique has evolved over 13 years and has yielded excellent results in the authors’ hands. Sixty-five consecutive patients at a mean follow-up of 47.4 months were reported as having a hernia rate of 1.5% and an incidence of mesh-related infection of 1.5%. The authors noted that the use of mesh has enabled them to harvest the entire rectus muscle, thus preserving all of the blood supply and intramuscular vascular connections within the muscle. They also stated that their technique allows the tightening and narrowing of the waist and abdomen, thus enhancing the aesthetic result of the TRAM flap donor site.


The authors compared clinical outcomes of two matched groups of patients with either bilateral unipedicle TRAM flap or bilateral DIEP flap breast reconstruction. The differences in abdominal wall strength were insignificant between the two groups for both hernias and bulges. Fat necrosis rates were significantly higher in DIEP flaps than in pedicled TRAM flaps. There were no significant differences in patient satisfaction, back pain, or physical function between the two groups. The authors concluded that although DIEP flaps represent an important technologic advance, bilateral unipedicle TRAM flaps remain an excellent option for breast reconstruction.


The cases of 335 patients treated over 6 years were reviewed. The author outlined the evolution of the operative procedure and reported an abdominal complication rate of 1.5% in his series, commenting that the last hernia occurred in the twenty-sixth patient. Of the first 300 patients, the new breast was completely shaped in one operation in 221 patients (58%). A total of 48% required revision of the reconstructed breast, and a small prosthesis was placed beneath the flap as a secondary procedure in 29 patients (7%). The overall complication rate in 335 patients was 8%, including 2 complete flap losses. Three patients had losses of at least 50% of the flap, 4 had losses of 25% to 50%, and 13 patients had losses of less than 25%. The author concluded that this procedure is complex and demanding. To perform the operation well, the surgeon must have a background in general surgery and should be experienced. He warned against the poorly prepared surgeon who performs this operation only occasionally; he predicted that these surgeons will have limited success and high complication rates.


Based on cadaver dissections of 34 rectus abdominis muscles, the authors confirmed the vascular anatomy of the inferior epigastric artery. In 82% of the muscles studied, the inferior epigastric artery bifurcated into two branches—medial and lateral—with the lateral artery dominant in 82% of specimens. This bifurcation occurred in the distal lateral third of the muscle. An average of 6.5 skin perforators with an external lumen diameter of 0.5 mm or larger was observed. The perforators were most dense in the middle lateral aspect of the middle third of the muscle. These anatomic studies demonstrate that it is possible to separate the muscle fibers from the dominant lateral branch of the inferior epigastric artery and associated veins and base a skin island extending from the lateral aspect of the rectus muscle to the inferior border of the scapula on specific myocutaneous perforating vessels. This technique has been successfully applied in 21 patients in whom the flap was transplanted to defects using microvascular techniques. It is advocated to preserve the continuity of the rectus abdominis muscle and avoid new complications and also to allow use of a thin flap for specific indications in reconstructive surgery.

The authors reviewed their experience with 60 patients between 1984 and 1991 who had inferiorly based rectus abdominis flap reconstruction. Microvascular transplantation as well as pedicle flap transfer was used for a variety of defects, including coverage of infected vascular prostheses for reconstruction of extremities. Twenty-four flaps were transferred microsurgically and all survived. Complications in this series were few. Of 60 patients, only two donor sites were repaired with Vicryl mesh. Four patients required a split-thickness skin graft to the abdominal donor site, and in four patients the umbilicus was displaced.

**Abdominal Wall Reconstruction**


This first report of a rectus abdominis myocutaneous flap described a superiorly based myocutaneous island flap for reconstruction of a contralateral upper abdominal wound following a shotgun blast. The authors suggested that this myocutaneous flap could be based superiorly or inferiorly on each of the pedicles to the rectus muscle.


Following resection of an extensive dermatofibrosarcoma of the upper abdominal wall, the author used two superiorly based rectus flaps that were rotated into the defect and a deltopectoral flap that was rotated downward to cover the secondary defect.

**Breast Reconstruction**


This paper represents one of the earliest reports on the anatomic basis of the DIEP flap and its use in 15 cases of breast reconstruction. The authors presented the anatomy of the flap, its dissection, and clinical outcomes, emphasizing the benefit of muscle-sparing harvest on abdominal wall function.


The authors from two centers, in Scotland and Yugoslavia, reviewed their experience with the first 50 patients undergoing free TRAM flap breast reconstruction. Forty percent of their patients were chronic smokers, 26% had low abdominal scars, 16% had postoperative radiation therapy, and 54% had postoperative chemotherapy. The average operating time was 5.6 hours and average blood loss was 2.4 units. Hospital stay averaged 11.2 days. Of significance were the complications, including three total flap losses (6%), two partial flap losses (4%), and abdominal hernia (4%). All the flap losses occurred in the first 20 patients. The last 30 patients experienced no flap loss or abdominal hernia. The authors modified their abdominal wall closure technique and reduced the abdominal hernia rate. The recipient vessels were all in the axilla. The circumflex scapular, thoracodorsal, and circumflex humeral arteries were most commonly used.


The authors reported their experience in two patients who underwent breast reconstruction with a bipedicled free TRAM flap. The patients had a lower midline inframamillary scar, and each half of the lower abdomen was elevated as a free flap based on the deep inferior epigastric vessels. Both inferior epigastric pedicles were sutured to recipient thoracodorsal and serratus vessels. Vein grafts were not used. The authors recommended this technique for reconstruction of large-breasted patients with extensive midline scarring below the umbilicus. They cited improved vascularity and reduced abdominal wall morbidity as the main advantages over the conventional bipedicle TRAM flap.

The authors reported their results with TRAM flap reconstruction in 23 women who had type II and type III obesity. The complications include fat necrosis in 20.5% of patients, skin loss of less than 10% in 8.8% of patients, and skin loss of 10% to 20% in 2.9% of patients. Abdominal wall complications include seroma (26.8%) and fat necrosis (11.7%). The authors concluded that despite the increase in complications in this obese group, satisfactory reconstructions were achieved and in the absence of other risk factors they did not think that obesity in and of itself was a contraindication to TRAM flap reconstruction.


Six patients who had TRAM flap reconstruction had seven normal deliveries. Unipedicle and bi-pedicle rectus harvest was performed on all patients, and all but one had a normal vaginal delivery. The infants were of normal weight. No abdominal revisions were required after pregnancy. They concluded that TRAM flap reconstruction will not prevent a normal pregnancy and delivery if the abdomen is prepared as described by Hartrampf.


In this original description of a superiorly based rectus abdominis myocutaneous flap with a vertical skin island, a burn scar contracture was released under the breast of a 12-year-old girl. The author speculated that this would be a useful flap for reconstruction in other areas. He suggested that resection of the costal cartilages and dissection of the internal mammary vessels will allow this island flap to be transposed to the head and neck area and the chest. He further speculated that the flap could be based inferiorly with an arc of rotation that would reach the groin and upper thigh. He stated that the flap is vascularized by arteries and veins of suitable diameter that would make it a good donor site for free flaps.


The author's technique for harvesting the TRAM flap, specifically donor site closure and abdominal wall evaluation, was described. The donor site was closed directly on the flap side and a similar plication was performed on the opposite side. Between October 1988 and December 1992 the author performed 151 breast reconstructions in 139 patients using the free TRAM flap. Twenty-four of the 139 patients had complications. There were three incidences of total flap loss and one incidence of partial flap loss. One patient developed abdominal laxity. In eight patients arterial or venous anastomosis thrombosis necessitated reexploration. In all patients the flap was salvaged without partial loss. Six patients had problems with umbilical loss or wound healing in the area of the umbilicus.


The authors reported their experience with immediate breast reconstruction using the TRAM flap in 54 patients over 3 years. In 10 patients the flap was transferred as a free flap, and the results were compared with those in the 44 patients who had a conventional TRAM flap. In the conventional TRAM flap group, partial flap loss and two cases of delayed healing of the mastectomy flaps occurred in six patients and abdominal relaxation in one. In the free TRAM group no flap loss and no other complications occurred. In this early report excellent results were obtained with both techniques, establishing that the free TRAM flap is as safe as the conventional technique and perhaps reduces the risk of abdominal complications and flap necrosis because of the more limited rectus muscle harvest. Larger series reported later confirmed the early findings reported by these authors.


The author reported on his first 82 patients in whom breast and chest wall reconstruction was performed using the transverse abdominal island flap. The anatomy of the abdominal wall was well described, and the technique for muscle harvest and abdominal wall closure was presented. Prolene mesh was used only in 3 of the 82 patients and other types of repair, including a fascial turnover and relaxing
incisions, in an additional four patients. Twenty of these patients were followed for 1 year or longer. All returned to their preoperative activity level without discomfort and reported that the abdominal wall appearance had greatly improved.


In this original description of the lower TRAM flap for reconstruction of the breast in eight patients, the authors presented their anatomic cadaver studies and clinical observations on abdominoplasties in establishing the vascular basis for this flap. In their first three patients the deep inferior epigastric vessels were ligated as a delay procedure 2 weeks before reconstruction. The final five patients underwent the operative procedure without a delay. All the flaps survived without any abdominal wall problems. However, the authors pointed out the potential for abdominal wall problems. They also presented eight other patients who had undergone vertical or upper transverse island breast reconstruction.


A patient who became pregnant 5 months after a unipedicle TRAM flap breast reconstruction developed a small hernia through the more cephalad portion of the rectus fascia during her pregnancy, but this had not caused her any problems and was never repaired. At the time of cesarean section, her obstetrician noted that her abdominal wall was attenuated and weak. Even with the small hernia, this patient was able to have a full-term pregnancy despite the TRAM flap harvest. Later reports by Hartrampf confirmed that successful pregnancy and vaginal delivery following TRAM flap reconstruction are possible.


A very large, wide vertical skin island was elevated on both superiorly based rectus flaps for reconstruction of the breast. This was the first report of a bipedicle myocutaneous rectus flap with a vertically oriented skin island. This was also the first report of partial muscle harvest. The authors left muscle medially and laterally as well as fascia to facilitate donor site closure. They stated that taking both muscles will improve the circulation to the flap, especially across the midline.


The anatomy, vascular basis, and the authors’ technique of flap elevation and donor site closure were presented. In a total of 662 patients the overall hernia rate was 1.4%, hernia requiring operative repair was 0.9%, abdominal laxity was 1.8%, and abdominal laxity requiring operative repair was 0.3%. When broken down into specific operations, unilateral single pedicle, unilateral double pedicle, and bilateral reconstruction, the total number of hernias was similar; however, abdominal laxity was seen in 1.7% of unilateral single pedicles as compared with 3.3% of bilateral pedicles. Abdominal laxity was seen in 3.3% of patients who had a mesh overlay as compared with 1.5% of patients who had direct closure. The authors attributed this acceptably low incidence of abdominal wall problems to the muscle-sparing harvesting technique and a meticulous repair.

Nahabedian MY, Tsangaris T, Momen B. Breast reconstruction with the DIEP flap or the muscle-sparing (MS–2) free TRAM flap: is there a difference? Plast Reconstr Surg 115:436, 2005.

The authors compared breast reconstruction using the deep inferior epigastric perforator (DIEP) flap and the muscle-sparing free transverse rectus abdominis myocutaneous (TRAM) flap (MS-2). The study evaluated 177 women who had breast reconstruction using muscle-sparing flaps over a 4-year period. Eighty-nine women had an MS-2 free TRAM flap procedure, of which 65 were unilateral and 24 were bilateral; 88 women had a DIEP flap procedure, of which 66 were unilateral and 22 were bilateral. The total number of flaps was 223. Mean follow-up was 23 months. For all MS-2 free TRAM flaps (113), outcome included fat necrosis (7.1%), venous congestion (2.7%), and total necrosis in (1.8%). For the women who had an MS-2 free TRAM flap, an abdominal bulge occurred in 4.6% after unilateral reconstruction and in 21% after bilateral reconstruction. The
ability to perform sit-ups was noted in 97% after unilateral reconstruction and 83% after bilateral reconstruction. The ability to perform sit-ups was noted in all women after unilateral reconstruction and in (95%) after bilateral reconstruction. These results demonstrated that there are no significant differences in fat necrosis, venous congestion, or flap necrosis after DIEP or MS-2 free TRAM flap reconstruction. The percentage of women who were able to perform sit-ups and the percentage of women who did not develop a postoperative abdominal bulge were increased after DIEP flap reconstruction; however, this difference was not statistically significant.


This is the original description of a vertical superiorly based rectus abdominis myocutaneous flap for breast reconstruction. The author presented his experience in four patients and emphasized the advantages of sufficient muscle bulk and subcutaneous tissues to obviate the need for an implant. The donor site was closed directly, with no reported complications in the four patients.


This was one of the early reviews of the TRAM flap and presentation of complications. The authors reviewed their experience with 63 flaps in 60 patients. The anatomy, including the intramuscular course of the vessels and the location of perforators, was well described. Complications included flap necrosis (11.7%), fat necrosis (0.6%), and abdominal wall hernia (8.3%). No deep vein thrombosis or pulmonary embolism was reported. The authors discussed these complications and made recommendations to minimize these risks.


In this second article on the transverse abdominal island flap, the authors detailed their surgical technique. They harvested the entire width of the muscle with overlying fascia. A wide tunnel from the abdomen to the chest was advocated. Closure of the rectus sheath with interrupted figure-of-eight sutures was described. Positioning and tailoring of the flap to match the opposite breast was discussed.


This was a prospective review of 211 free TRAM breast reconstructions performed in 163 patients. Forty-eight patients had bilateral reconstruction. In 108 of the 211 reconstructions the muscle-harvesting technique entailed splitting the muscle. Total flap loss occurred in 3 of 211 flaps, for a success rate of 99%. Complications were seen in 81 of 211 reconstructions for a complication rate of 38% overall—fat necrosis or partial flap loss (7%) and hernia or bulge (5%). The authors commented that the bulge hernia rate tended to be lower in the group that had partial muscle harvest. Interestingly, the fat necrosis rate was slightly higher in the group who had partial muscle harvest. However, none of these differences reached statistical significance. The authors pointed out that a significantly higher incidence of fat necrosis was seen in smokers.


The authors reported their experience with the superior pedicle and free TRAM flap for breast reconstruction. They reviewed 68 breast reconstructions in 63 patients. Of these, 71% were conventional TRAM flaps and 29% were free TRAM flaps. Of the conventional TRAM flaps, 54% were unipedicle flaps and 46% were bipedicle flaps. All patients underwent immediate TRAM flap reconstruction. One fourth of the patients in each group were cigarette smokers. The following differences between the two groups were noted: 44% of the patients with conventional TRAM flaps required postoperative chemotherapy, and in 29% of these patients postoperative chemotherapy was delayed because of complications of the TRAM flap. In contrast, only 14% of the patients in the free TRAM flap group had chemotherapy delayed because of complications. Partial flap necrosis occurred in 17% of the patients with conventional TRAM flaps and none in those with free TRAM flaps.
This was statistically significant. Fat necrosis occurred in 23% of conventional TRAM flap patients and in none of the free TRAM flap patients.


The authors reviewed the extensive experience of the senior author (JMS), together with meta-analysis data regarding fat necrosis rates, abdominal wall strength, amounts of muscle harvested, and flap loss rates. The meta-analysis data suggest that fat necrosis rates are twice as high in DIEP flaps compared with muscle-sparing free TRAM flaps. Flap loss rates were also doubled in DIEP flaps. SIEA flaps had a higher thrombotic rate than DIEP or free TRAM flaps. Abdominal strength did not vary among MS-2 free TRAMs, DIEP flaps, and SIEA flaps for unilateral cases, but in bilateral cases, SIEA flaps obviously demonstrated more complete early recovery of the abdominal donor site. A useful algorithm for selecting SIEA, DIEP, or MS-2 free TRAM flaps was presented.


To improve the reliability of the skin island, the authors advocated a midabdominal transverse island. They reviewed their experience with 236 flaps in 223 patients. They reported a 2.2% incidence of abdominal wall hernia over 4 years; no total flap loss was seen and partial flap loss (greater than 10% of surface area) was observed in five patients. The authors stated that the midabdominal location of the island not only improves the vascularity of the skin island but also reduces the risk to the abdominal wall compared with the lower transverse island. This 2% risk of abdominal wall problems and 2% risk of partial flap loss is superior to that reported for the lower transverse island.


This was the original description of the upper transverse abdominal flap for breast reconstruction. The authors presented their experience in five patients. Their first three patients underwent a delay procedure; the final two patients underwent reconstruction without a delay. This is essentially an upper rectus abdominis transverse island based on the perforators through the upper part of the rectus muscle. They accurately described the basis of this flap as the perforating vessels from the superior epigastric artery and vein through the rectus abdominis muscle.


Of 500 patients undergoing TRAM flap reconstruction, 341 patients had unilateral breast reconstructions. In 19% of the patients a double-pedicle TRAM flap was used for a unilateral reconstruction. However, in the most recent 50 unilateral modified radical mastectomy reconstructions, the double-pedicle TRAM flap was employed 60% of the time. Their indications for the double-pedicle TRAM were as follows: (1) patients in whom the volume of tissue necessary to match the normal breast exceeded that which can be reliably carried on a single pedicle and (2) patients who fell into one of the high-risk categories, including obesity, chest wall radiation, and a history of cigarette smoking. Patients with lower abdominal scars were also included in the high-risk group. The technique of the operative procedure was well described.

Chest Wall Reconstruction


The authors presented this “new” technique using a double-pedicle transverse rectus abdominis flap for breast reconstruction and chest wall reconstruction in 15 patients. Indications for the double pedicle included exceptionally large soft tissue requirements, prior abdominal operations, and certain high-risk patients, including smokers and those with irradiated chest walls. They reported complications of partial tissue loss in two patients, abdominal flap seroma in one patient, and hernia in one patient.
The double pedicle was shown to improve the vascular supply to the transverse island and allow the transfer of extremely large and long transverse flaps for breast reconstruction.


The authors presented the 20-year Emory University experience with more than 350 procedures for sternal wound closure. A majority of the cases were closed with pectoralis major flaps, but 5% of the cases were closed with superiorly based rectus abdominis muscle flaps. Most flaps were raised as isolated muscle flaps, although several VRAM flap were used. Although the procedures worked well for the most part, caution was advised when using the distal portion of the muscle to reach the manubrial area of the sternum, because the choke system anastomosis with the deep inferior vessels may be poor in vasculopaths, resulting in ischemic necrosis of the tip of the flap. Additionally, the donor site in a muscle-only harvest can undergo ischemic necrosis of the skin as a result of the removal of direct cutaneous perforators and a lack of collateral circulation. When a myocutaneous flap is raised, the skin island should be kept fairly proximal over the muscle to again prevent tip necrosis.


Extensive chest wall defects following recurrent breast cancer, radiation ulceration, or extensive chest wall resections were reconstructed with TRAM flaps. The authors reported a high complication rate, including 11 hernias in 15 patients. In discussing the article, Hartrampf stated that he had a hernia rate of 0.5% in his current series of 210 patients. He noted that a hernia rate in 11 out of 15 patients is unacceptable and pleaded that muscle- and fascia-sparing techniques for harvesting of this flap be used to reduce abdominal wall complications.


The authors presented three patients in whom complete sternectomy for chronic osteomyelitis was followed by successful reconstruction with a rectus abdominis myocutaneous island flap. The volume of the skin and muscle successfully obliterated the defect following the resection. The authors encountered no complications and advocated this as an excellent alternative for chronic osteomyelitis of the sternum.

Groin Coverage


An inferiorly based rectus abdominis flap was used to cover an extensive complex defect of the groin after a close-range shotgun injury. The femoral vessels were reconstructed with a Gore-Tex graft and secondarily covered with an inferiorly based rectus abdominis flap.


A large transverse upper abdominal skin island is carried on an inferiorly based rectus abdominis muscle for coverage of a chronically infected radionecrotic wound of the right groin. This early report demonstrated the extensive arc of rotation of the inferiorly based rectus abdominis flap and its application for coverage of defects in the groin, perineum, and upper thigh.


The authors used the inferiorly based rectus abdominis flap for groin reconstruction. They reported successful reconstruction in eight patients. Synthetic mesh was used for reconstruction of the donor defect in four patients. By directing the skin island diagonally from the umbilicus toward the posterior axillary line, the authors stated that this design away from the so-called low venous pressure zones improves the venous return of the flap by including more cutaneous and subcutaneous venous interconnections.
Head and Neck Reconstruction
In a patient who had undergone resection of an extensive neurofibrosarcoma, a vertically oriented rectus abdominis myocutaneous free flap was based on the deep inferior epigastric vessels for reconstruction. In addition to the vertical island, a small transverse skin island was also elevated. The bulk of the flap was used to obliterate the dead space and to provide skin coverage.

Hip Reconstruction
In three patients the rectus abdominis muscle was used to fill in dead space, provide soft tissue coverage, and to provide a reliable vascular supply for the control of chronic osteomyelitis of the hip. There were no complications in this group of three patients. In one patient the muscle was passed through a subcutaneous tunnel; in the other two patients the muscle was passed through a hole in the acetabulum. The author successfully demonstrated the usefulness of this muscle in reconstruction of defects around the upper thigh and within the hip.

Lower Extremity Coverage
In this case report the authors used an inferiorly based vertical rectus abdominis myocutaneous flap for coverage of an above-knee amputation stump. The large size of the flap and long arc of rotation made this a suitable flap for salvage of an above-knee amputation.

Penile Reconstruction
The authors presented their experience with penile reconstruction in four patients. These included three transsexuals and a pseudohermaphrodite. A modified TRAM flap based on the deep inferior epigastric artery was used for reconstruction.

Upper Extremity Coverage
The authors reported their experience in six patients in whom the rectus abdominis muscle was transferred in stages as a pedicle flap or in one stage as a free flap for coverage of hand soft tissue defects. The muscle was covered with a skin graft. Although this would not be the first choice for hand coverage, the authors suggested that it makes a satisfactory alternative.

A superiorly based rectus abdominis muscle flap was used for coverage of the elbow in a staged procedure. The muscle was divided 3 weeks after the original procedure. The feasibility of using the rectus abdominis for coverage of the elbow was demonstrated.

Vaginal Reconstruction
The authors reported their experience with 11 vaginal reconstructions and nine pelvic defect reconstructions over 3 1/2 years. In their 20 patients, partial flap loss occurred in only two. There was no case of major flap loss and no other complications, specifically those involving the abdominal wall donor site.
Flap Modifications

The authors presented their experience in 34 patients who underwent coverage of extensive chest defects following mastectomy. A large abdominal skin flap based on the rectus abdominis myocutaneous perforators was described. This large flap is based on perforators on the opposite rectus abdominis. The flap elevation proceeds across the ipsilateral rectus and across the midline to the perforators on the opposite side. Some extensive defects were closed satisfactorily with this rather large flap. These authors first demonstrated that perforators from one rectus abdominis could easily support the skin on the opposite side.


The authors described the “recharged” TRAM flap. During this procedure a standard pedicle TRAM flap is elevated on one side. The deep inferior epigastric vessels to this side are also dissected and divided. On the opposite side, essentially a free TRAM flap is elevated, including division of the muscle and vascular pedicle. Then the deep inferior epigastric vessels on each side are sutured to each other to establish flow from the superior epigastric vessel on the pedicle side through the muscle into the deep inferior epigastric vessel and across the anastomosis into the deep inferior epigastric system on the opposite side. It is thought that this will increase the circulation on the opposite side and improve the venous drainage. This flap modification is extremely useful in patients with a lower midline scar in whom the entire lower abdomen is elevated. This is an alternative to the bipedicle TRAM. The authors described their technique and presented their experience with this method. In 22 patients there was a 4.5% incidence of partial flap loss, a 4.5% incidence of flap necrosis, and a 4.5% incidence of abdominal skin loss and abdominal weakness.


A series of 23 high-risk patients who underwent 30 immediate TRAM flap reconstructions was reviewed. Flap delay was achieved by ligation of the superficial and deep inferior epigastric arteries 2 weeks before elevation and breast reconstruction. Fat necrosis occurred in only one patient (a 4.3% incidence). A comparison of blood pressure in the proximal stump of the deep inferior epigastric artery and vein in seven study patients and 13 low-risk undelayed patients (controls) showed an overall increase in arterial pressure from 13.3 mm Hg (control) to 40.3 mm Hg (delayed). The data suggest that TRAM flap delay in the high-risk patient improves flap safety.


The authors described the use of a very long thoracoepigastric flap based on the perforators from the ipsilateral rectus abdominis that extends well beyond the posterior axillary line. This is a delayed flap that can extend onto the posterior trunk. Breast reconstruction was performed using this flap and a silicone implant.


A case report of sternal wound infection after coronary artery bypass surgery was presented. The patient had undergone bilateral internal mammary artery grafting. Despite this, the authors were able to successfully reconstruct the defect with a vertical rectus abdominis flap basing it on the eighth anterior intercostal vessels. A successful outcome was reported. The authors speculated that ligation of the internal mammary may have had some “delay” effect on the rectus abdominis and improves the circulation through the eighth intercostal vessel.


The extended epigastric flap originally described by Taylor was used as a pedicle flap in four patients for coverage of large wounds of the abdomen, groin, and thigh. In two patients the flap was success-
fully transferred microsurgically for reconstruction of the head and lower extremity. No flap loss, either partial or complete, was reported.


A superiorly based rectus abdominis muscle flap with a patch of anterior rectus fascia was successfully transposed for closure of the right ventricular defect. This case report underscores not only the versatility of the rectus flap but also the useful application of reconstructive surgical procedures in life-threatening situations.


The authors transferred the vertical abdominal fasciocutaneous flap they described in 1986 as a free flap. In elevating it as a free flap a portion of the anterior rectus sheath together with underlying rectus muscle is harvested superiorly to include the superior epigastric artery. In effect, this is a myocutaneous flap with a fasciocutaneous extension beyond the muscle. This provided a thin flap that was successfully used for reconstruction of facial defects. The authors reported their successful reconstruction in three patients.


A superiorly based vertical abdominal fasciocutaneous flap was used for reconstruction of chest wall defects in eight patients. The flap was based on rectus abdominis perforators in the upper part of the muscle. The base of the flap was designed just below the costal margin, and the rectus muscle was spared. The authors emphasized that in the proximal part of the dissection, all perforating vessels at the level of the costal margin should be preserved and included as the pedicle to the flap.


The rectus abdominis has a role in coverage of the infected median sternotomy wound. However, on occasion the distal end of the superiorly based rectus muscle does not provide an excellent blood supply. On other occasions one or both internal mammary arteries may have been ligated. In an effort to use a single rectus muscle to cover the entire defect, the authors advocated microsurgical anastomosis of the deep inferior epigastric vessels to recipient vessels in the upper chest (supercharging). Thus flow is reestablished into the muscle through the deep inferior epigastric vessels as well as the superior epigastric vessels. The authors presented their experience in six patients. They were successful on each attempt and recommended this procedure over the use of multiple flaps for coverage of extensive median sternotomy defects.


An upper transverse island base designed just below the costal margin was described. The skin island was based on the deep inferior epigastric vessels of the underlying rectus abdominis muscle. This proved to be an extremely useful flap with a rather wide arc of rotation that provides a large volume of skin subcutaneous tissue for reconstruction of defects in the lower abdomen, groin, and thigh. The authors reported that complications were few but did not elaborate further.


The authors successfully transferred a rectus abdominis muscle flap to the lower extremity. The flap was then split longitudinally so that one portion covered the lateral malleolus and the other half the medial malleolus in the same leg.


In this anatomic and clinical study, the authors described the extended deep inferior epigastric flap. Based on the deep inferior epigastric artery a muscle flap with a diagonally placed upper skin island
was designed. This is a particularly long myocutaneous flap, with an arc of rotation extending down to the knee and is available as a free flap with an extremely long pedicle.


In this brief case report the authors reconstructed an extensive chest wall defect with a superiorly based vertical rectus abdominis flap, including the external oblique fascia from the ipsilateral side. The skin island extended to the contralateral side of the abdomen.

Complications


To minimize the risk of abdominal wall weakness and hernia, the authors advocated reconstruction of the anterior rectus sheath with double Mersilene mesh extending up to the costal margin and the same width as the fascia taken with the muscle pedicle. In essence, Mersilene mesh replaces the anterior rectus sheath. The authors reviewed their experience with 186 TRAM flap breast reconstructions. Of these, 31 patients underwent direct closure of the anterior rectus sheath; 43% developed weakness, bulging, or hernia, five of whom required secondary repair. In 155 patients the donor defect was closed with Mersilene mesh and only 4% developed bulging that required later repair. The authors attributed this to technical errors. They also reported two patients with infection and three with exposed mesh due to necrosis. In none of these patients was the mesh removed. In a discussion of this article, Hartrampf vehemently disagreed with the authors and advocated a muscle- and sheath-sparing technique. In his experience with 216 patients, he reported that 145 patients in whom unilateral pedicle flaps were used had all undergone direct closure without synthetic mesh. Only one single lower abdominal hernia occurred because of a technical error. He advocated the removal only of that portion of the rectus muscle and sheath that is necessary to include the periumbilical perforators with the superior epigastric vessels. This debate over abdominal wall closure and partial or total harvesting of the muscle continues to this day.


The authors advocated preoperative evaluation, preoperative flap design, and technical modifications to minimize the risk of complications. Patients who are obese with a large abdominal panniculus are considered poor candidates. Smokers may have a higher risk of flap necrosis. Flap design on the contralateral rectus allows a more gentle arc of rotation, thus minimizing the risk of kinking. Identification and protection of the myocutaneous perforating vessels are emphasized. Abdominal wall reconstruction with Prolene mesh was recommended.


This retrospective review of 130 TRAM flaps at M. D. Anderson Cancer Center dealt specifically with abdominal wall problems. True hernias as well as abdominal wall bulges and weakness were included. The patients were divided into three groups: in group 1, the entire muscle was harvested with a one-layer anterior sheath closure. In group 2, the lateral third of the muscle was preserved and the fascia was closed in two separate layers—the deeper muscle layer and the anterior layer. In group 3, more muscle was harvested, leaving only the lateral fifth of the muscle with a two-layer closure. The authors stated that the deep or muscle layer is a “stronger” closure, since it approximates muscle remnants and internal oblique fascia to the midline fascia deep to the linea alba. The superiority of the closure in group 3 was statistically significant. The incidence of bulging or weakness was 33% for group 1, 40% for group 2, and only 8% for group 3. There were four true hernias in group 1, one in group 2, and none in group 3.
The experience in these patients was neither simultaneous nor randomized; rather, it was a chronologic evolution of abdominal wall closure in their hands. Nahai in a discussion of this article emphasizes that experience with the TRAM flap is important in reducing complications.


Fifty-seven patients who had undergone breast reconstruction with the TRAM flap were evaluated. Thirty-three patients had only one muscle harvested and 24 patients had both muscles harvested. The patients were evaluated 6 months and 2 years after breast reconstruction. In all patients the rectus sheath was reconstructed with Teflon mesh. A detailed and complex evaluation of the patients included clinical examination by the surgeon at least 6 months after the operation and a questionnaire on abdominal comfort, strength, and ability to do sit-ups and participate in sports between 6 months and 2 years after the operation. A functional evaluation of the abdominal wall was performed by a physiotherapist, and CT scans of the abdominal wall were obtained before and after TRAM flap reconstruction to assess the relationship of the abdominal wall musculature. The authors reported that Teflon mesh was well tolerated, with no hernia or bulging. Ten patients reported less back pain after the operation than before. They also found that the ability to do sit-ups and participate in sports was the same as preoperatively. Physiotherapeutic evaluation of the abdominal muscle did show a decrease in function of the abdominal wall, more so in bilateral cases. CT scans demonstrated a medial migration of the lateral abdominal musculature, leaving only a small central portion of the abdominal wall devoid of muscles.


The authors presented their experience with inferiorly based rectus abdominis flaps in 26 patients between 1988 and 1993. In 17 of these patients, the flap was used as a pedicle flap, and in nine patients it was transferred as a free flap. The authors reported that patients with multiple injuries, especially those who had recently undergone abdominal laparotomy, had a significantly higher morbidity rate. Dehiscence of the abdominal wound in three patients and a fatal donor site infection after rectus flap transfer were reported. They recommended that alternate sources of tissue should be used rather than the rectus abdominis in patients who are seriously ill, those on ventilators, or those with abdominal distention and nutritional compromise.


This was an extensive review of the first 556 patients to undergo TRAM flap breast reconstruction at Emory University. The anatomy of the flap and operative technique were outlined. Of interest is the classification of risk factors and the relationship of these factors to complications in the breast as well as the abdominal donor site. Complications included partial flap loss (5%), total flap loss (0%), fat necrosis (10.6%), and abdominal hernia (8.8%). The overall complication rate was 23.7%, including pulmonary embolus and deep venous thrombosis (0.7%), wound infection (5%), and hematoma (1.3%). Of interest were the association of risk factors with complications. Smokers had an overall complication rate of 39.2% versus 21.4% in nonsmokers. This with a history of radiation therapy led to a complication rate of 37.4% versus 21.1% in those who did not have radiation therapy. Significant abdominal scars led to a 32.9% complication rate versus 20.6% in those without significant abdominal scars. Obesity was associated with a 31.4% complication rate versus 20.8% in nonobese patients. Complication rates before and after age 60 were similar. Also of interest were risk factors and their association with fat necrosis. These included radiation, abdominal scars, obesity, smoking, and hypertension. In all of these categories the risk of fat necrosis was higher. Smoking, history of radiation, significant abdominal scarring, and obesity were all shown to be statistically significant factors for overall complications, including abdominal wall problems, partial flap loss, and fat necrosis.
ANATOMIC LANDMARKS

**Landmarks**
The external oblique muscle is the most superficial of the three lateral abdominal muscles, extending between the costal margin and the iliac crest and inguinal ligament. It is a thin, quadrilateral muscle with an aponeurosis that blends with that of the internal oblique muscle to form the anterior rectus sheath.

**Size**
40 × 20 cm.

**Origin**
The muscle arises from the lower eight ribs laterally as fleshy digitations combining to form a single large muscle sheet.

**Insertion**
Anterior half of the iliac crest and a broad aponeurotic insertion into the linea semilunaris, where it fuses with the anterior leaflet of the internal oblique to become the anterior rectus sheath more medially.

**Function**
Stabilize abdominal core.

**Composition**
Muscle, myocutaneous.

**Flap Type**
Type IV.

**Dominant Pedicle**
Segmental lateral cutaneous branches of the inferior eight posterior intercostal vessels, with minor contributions inferiorly from the ascending branch of the deep circumflex iliac artery (DCIA) vessels.

**Minor Pedicle**
Ascending branch of the deep circumflex iliac artery.

**Nerve Supply**
Intercostal.
Section 10C

ABDOMEN

External Oblique Flap

CLINICAL APPLICATIONS

Regional Use
  Chest
  Posterior trunk
  Abdomen
ANATOMY OF THE EXTERNAL OBLIQUE FLAP

Fig. 10C-1

Dominant segmental pedicle: Lateral cutaneous branches of inferior eight posterior intercostal arteries
Minor pedicle: Ascending branch of deep circumflex iliac artery
ANATOMY

Landmarks
This muscle is the most superficial of the three lateral abdominal muscles, extending between the costal margin and the iliac crest and inguinal ligament. It is a thin, quadrilateral muscle with an aponeurosis that blends with that of the internal oblique to form the anterior rectus sheath.

The external oblique muscle is located between the linea semilunaris (palpated at the lateral edge of the rectus muscle) and the anterior axillary line and extends from the lateral costal margin to the iliac crest.

Composition
Muscle, myocutaneous.

Size
40 × 20 cm. The flap territory extends from the midline of the abdomen to the anterior axillary line.

Origin
The muscle arises from the lower eight ribs laterally as fleshy digitations combining to form a single large muscle sheet.

Insertion
Anterior half of the iliac crest and a broad aponeurotic insertion into the linea semilunaris, where it fuses with the anterior leaflet of the internal oblique to become the anterior rectus sheath more medially.

Function
Stabilize abdominal core.

Arterial Anatomy (Type IV)

Dominant Pedicle
Segmental lateral cutaneous branches of the posterior intercostal arteries

REGional Source
Thoracic aorta.

Length
3 cm.

Diameter
0.5 to 1 mm.

Location
These segmental vessels enter the posterior muscle belly at the level of the midaxillary line.

Minor Pedicle
Ascending branch of the deep circumflex iliac artery

REGional Source
External iliac artery.

Length
4 cm.

Diameter
0.5 to 1 mm.

Location
3 cm superior to anterior superior iliac spine.

Venous Anatomy

Venae comitantes accompanying the arterial circulation; source vessels include the azygous and hemizygous veins.

Nerve Supply

Motor
Seventh through twelfth intercostal nerves.

Sensory
Seventh through twelfth intercostal nerves.
Vascular Anatomy of the External Oblique Flap

Fig. 10C-2

Dominant segmental pedicle: Lateral cutaneous branches of inferior eight posterior intercostal arteries (arrows)
**FLAP HARVEST**

**Design and Markings**

*Skin Islands*

The external oblique muscle is most commonly used as a rotation advancement flap for chest or hip defects or as part of a component separation procedure for hernia repair. Incorporation of a modified V-Y approach using a backcut can assist with flap advancement. The skin island may extend over the territory of the rectus muscle to the midline of the abdomen. The flap naturally rotates superiorly because of the direction of its fibers.

Fig. 10C-3

Superior skin island design

The most common incision is a curvilinear incision starting below the lower rib margin posteriorly and extending transversely across the subcostal area before turning down parallel and adjacent to the linea semilunaris. This vertical limb descends until the umbilicus is reached, at which point the incision is curved back toward the ASIS.

**Patient Positioning**

The patient is placed in the supine position, and if necessary, padding is placed beneath the ipsilateral buttock to further expose the flank.
GUIDE TO FLAP DISSECTION

Standard Flap

The skin is deepened to the fascia, and the flap is raised from medial to lateral. The dissection is in the subcutaneous plane until the semilunar line is reached. At the lateral edge of the rectus sheath, the fibers of insertion of the external oblique muscle to the linea semicircularis are divided, releasing the skin island with the external oblique fascia and muscle. The external oblique fascia is elevated, with the plane of dissection now located between external and internal oblique muscles. In the inferior lateral abdominal wall the external oblique fibers of origin from the anterior half of the iliac crest are divided.

The muscle is released from the costal margin to allow rotation of the flap superiorly. Care must be taken to preserve two to four segmental vascular pedicles entering the deep surface of the muscle adjacent to its origin from the costal margin.
FLAP VARIANTS

- Rotation advancement/V-Y flap
- Tissue expansion
- Component separation
- Reverse flap

Rotation Advancement/V-Y Flap
In this variant, dissection of the flap is the same as for the standard flap. This design takes advantage of the lower abdominal excess to bear the tension of closure inferiorly while supporting the flap superiorly. Care is taken to extend the design inferiorly. Flap elevation is similar to that of the standard flap. Release of the muscle origin from the costal margin superiorly and release of the muscle insertion from the iliac crest may be required to increase the flap advancement. The V-Y variant requires an oblique inferior backcut, as illustrated below, to allow a cephalad flap motion that creates a vertical V-Y closure.

Fig. 10C-5
Tissue Expansion
One way to increase available fascia for abdominal wall reconstruction is through tissue expansion. An expander is placed through a remote incision (never the IMF) into the space between the external and internal oblique muscles. Once expansion is complete, a normal direct closure or component release can be performed after the expander is removed.
Component Separation
Since Ramirez’s description of the component separation technique, using external oblique elevation to facilitate release of and advancement of the rectus abdominis medially has become the flap of choice in abdominal hernia repair. The procedure involves incising the external oblique fascia just lateral to the linea semilunaris and undermining it to the anterior or midaxillary line. The mobilized external oblique provides relaxation for the rectus abdominis and associated fascial support structures to advance medially, allowing closure of the abdominal hernia centrally. Although technically not a direct use of the external oblique as a flap for coverage, its elevation and release is integral to the success of the component separation procedure.

![Component Separation Diagram](image)

**Fig. 10C-7** Cross-sections of the dissection of the abdominal wall into its component sections and final flap reconstruction.

Reverse Flap
The muscle and fascia of the external oblique flap can be used for reconstructing back defects. Based on the intercostal vessels, the muscle and fascia are released along the semilunar line, along the costal margin, and from the ASIS. Bilateral flaps can reach the posterior midline.
ARC OF ROTATION

Standard Flap
The point of rotation occurs at the edge of the costal margin at the anterior axillary line. The flap will reach the anterior and posterior trunk.

![Diagram of ARC OF ROTATION](image)

**FLAP TRANSFER**
The flap is transferred to its recipient site, without undue tension on the segmental blood supply. Because of the downward oblique direction of the muscle fibers, the flap will transfer superiorly more easily than inferiorly.

**FLAP INSET**
This myocutaneous unit is directly inset into the defect. The deep fascia beneath the skin island may be used to reconstruct a chest wall, pelvic, or adjacent abdominal wall defect. By insetting the flap’s fascia into the defect, tension is removed from the skin closure.

**DONOR SITE CLOSURE**
No fascial closure is required. The large donor site requires drains postoperatively. Either the rotational/advancement or V-Y site will close primarily. One can place a skin graft if needed. The skin defect is closed directly by advancement of the remaining abdominal and groin skin.
CLINICAL APPLICATIONS
This 70-year-old woman with lung cancer metastatic to her chest wall underwent radical chest wall resection (rib and pleura only) with reconstruction using two Gore-Tex sheets. She developed an infection around the Gore-Tex, with subsequent abscess formation and wound breakdown. The cardiac service planned explantation of the mesh and requested plastic surgical closure of the two wounds. The upper anterior wound was closed with a pectoralis major myocutaneous flap. The lower lateral wound required an external oblique myocutaneous rotation advancement flap to achieve closure. She had a remarkably uneventful postoperative recovery, with complete resolution of both the sepsis and the chest wall pain.

Fig. 10C-9  A, Resection of empyema and recurrent lung cancer. B, The external oblique muscle raised for closure of the lower thoracic wound. C, The healed result is shown. (Case supplied by GJ.)
This 87-year-old woman had an 11-year disease-free interval from cancer of the right breast and presented with a chest wall recurrence. Her chest wall excision included muscle but not ribs. She had undergone radiation therapy 11 years earlier. The size and location of the defect and the advanced age of the patient made the external oblique an ideal choice.

**Fig. 10C-10**  
A, The defect with exposed irradiated ribs and the planned external oblique flap. The design does not cross the midline and includes all potential lateral intercostal neurovascular bundles.  
B, The flap has been elevated to the level of the intercostal bundles and released from the costal margin.  
C, Flap inset. No inferior backcut was needed to advance the flap.  
D, Patient at 2 weeks after suture removal. Convalescence was remarkably easy compared with a latissimus dorsi or rectus abdominis flap. (Case supplied by MRZ.)
This 50-year-old woman had undergone breast conservation therapy for a right breast cancer 10 years earlier. She presented with a submammary recurrence, and a wide excision of the mass and completion mastectomy were performed. An external oblique flap was chosen for her reconstruction. The opportunity for implant reconstruction still exists, because a tissue expander can be placed under the flap in delayed fashion.

Fig. 10C-11  A, Preoperative photo showing the submammary scar from her biopsy and the proposed skin resection with mastectomy. The flap design is not affected by the previous suprapubic scar. B, The defect after resection, with some partial rib removal. The intrathoracic space was not entered. C, The flap was elevated to the lateral intercostal vascular bundles. A backcut was performed to allow tension-free advancement. D, Flap inset. E, The patient is shown at 1-month follow-up. The flap design did not distort the umbilicus, a common problem with the vertical rectus abdominis myocutaneous (VRAM) flap. (Case supplied by MRZ.)
This 58-year-old woman had a history of a left chest wall liposarcoma initially treated with chest wall resection, Gore-Tex repair, and latissimus flap coverage. After accidentally burning her insensate flap and exposing the Gore-Tex, the chest wall was salvaged with an omentum flap and skin graft. Five years later, she had a recurrence requiring a wide chest wall resection. She was referred for a free flap, since she was not thought to be a candidate for a locoregional flap because of the prior surgery and her previous abdominal surgery. An external oblique flap was planned, because the lateral intercostal blood supply was intact, and the flap was “delayed” by her prior surgery. She tolerated the surgery with minimal morbidity and avoided the risks of free tissue transfer.

**Fig. 10C-12**  
A, The patient’s defect is seen after wide resection of full-thickness chest wall and a Marlex mesh sandwich repair. Evidence of the previous latissimus dorsi and skin-grafted omentum are visible, as well as the previous midline surgery.  
B, The planned external oblique flap. The patient was prepared for a skin graft to the donor site.  
C, Flap inset. A small backcut was required to advance the flap. Because of the horizontal laxity of the abdomen, a primary closure was obtained without the need for back-grafting.  
D, Patient at her 2-week follow-up for suture removal. Her recovery was uneventful and significantly less morbid than would have been the case with the requested free flap. (Case supplied by MRZ.)
This is an unusual case of melanoma of the breast in a 44-year-old woman. She required an extensive chest wall resection, and it was clear that no one flap would allow primary closure of the resultant defect. In such circumstances, the defect is divided into an upper and lower defect, each reconstructed with a different flap. In this case, a VRAM flap was used for the upper portion, and the external oblique flap was used for the lower component. This combination is advantageous because it does not require a position change, the horizontal laxity of the abdominal area can be used to advantage, and primary closure of the donor site can be obtained.

Fig. 10C-13  A, Proposed wide resection of the right chest, including mastectomy and axillary lymph node dissection. B, Defect after resection, which included all muscular fascia, but no muscle or rib resection. C, The VRAM flap has been elevated on the contralateral pedicle and rotated to close the superior defect. The external oblique flap has been elevated to close the lower defect. In cases in which the contralateral mammary has been divided by the chest wall resection, a latissimus dorsi flap would be used for the superior defect. Mammary artery division does not affect the external oblique flap. D, Flap inset with primary closure of the donor site. The patient did have some marginal necrosis at the abdominal midline scar requiring a minor revision. She otherwise healed uneventfully. (Case supplied by MRZ.)
This 61-year-old woman presented with an angiosarcoma of the right chest after chest wall irradiation for breast cancer. The patient had a wide excision and wound-VAC dressing until negative margins were obtained. A VRAM flap was planned for the defect, but primary closure was not obtainable. The external oblique flap could then be elevated, providing additional tissue for a two-flap closure without a change of position or field. This strategy is useful if the surgeon is unsure whether the VRAM or latissimus flaps will provide enough tissue for primary closure.

Fig. 10C-14  A, Final defect after multiple reexcisions performed and negative margins were finally obtained. This is not uncommon in cases of angiosarcoma, where the extent of disease is often underestimated. Note the hyperpigmentation from previous radiation therapy. B, Planned VRAM flap to reconstruct the entire defect. C, Once the flap was elevated and rotated, it became clear that the VRAM would not supply enough tissue, so an external oblique flap was elevated in addition. D, Flaps inset and primary closure obtained at all sites. E, The patient had some necrosis at the tip of the VRAM flap near the axilla that required conservative debridement in the office and secondary healing with dressing changes. She is shown at her 9-month follow-up. (Case supplied by MRZ.)
This 78-year-old woman had a large, malignant fibrous histiocytoma that precluded her lying supine; the lesion was quite painful and malodorous. Her entire back had previously been irradiated.

Fig. 10C-15  A, The excised tumor and marginal back tissue are shown, with exposed and partly resected spinous processes. B, The patient was placed in the supine position for elevation of both flaps. C, She was turned to the prone position for the flap inset. The upper right flap has a duskier color as a result of the necessary division of the uppermost perforators to the flap. The skin graft did not take over this area. D, The incisions that preserved the periumbilical perforators to the abdominal skin are shown. (Case courtesy Gregory Ara Dumanian, MD.)
This 48-year-old woman had a massive dermatofibrosarcoma protuberans excised from her left flank. She had undergone preoperative radiation therapy. The spinous processes were exposed.

**Fig. 10C-16**  An external oblique turnover flap was performed, and a skin graft to cover the left flank. A random skin flap of right back skin was transposed to cover the spinous processes. (Case courtesy Gregory Ara Dumanian, MD.)

**Pearls and Pitfalls**

- Prior incisions through the external oblique fascia or rectus sheath may preclude use of this flap.
- Careful donor site closure is required. Avoiding injury to the intercostal nerves will prevent bulges postoperatively.
- This myocutaneous flap has a limited arc of rotation that is primarily useful as an alternative flap when a reliable flap such as the rectus abdominis myocutaneous flap is not available.
- Care should always be taken to preserve the posteriorly based vascular supply during dissection, bearing in mind the limitation of truly segmental inflow.
- The external oblique flap is an excellent choice for lower third chest wall defects.
EXPERT COMMENTARY
Gregory Ara Dumanian

Advantages and Limitations
The external oblique flap is a useful tool in a surgeon's armamentarium for reconstructing lower chest/upper abdominal wounds and flank defects caused by tumor extirpation. Radiation therapy obviates closing these wounds with simple skin grafts. Although in my opinion the external oblique muscle is not a first-line flap choice for these wounds, it offers certain advantages over alternatives. The choice to use the external oblique flap depends on how the surgeon views the interplay of radiation and skin grafts.

Radiation Therapy Before Tumor Excision
Radiation therapy is commonly performed before tumor excision for tumors of the flank and anterior chest. Sarcomas of the back and significant breast cancers are commonly treated with preoperative radiation therapy. The defect remaining after tumor excision would potentially be closeable with skin grafts and subatmospheric dressings; however, the success rate of placing skin grafts on an irradiated bed would be lower rather than higher. Skin grafts tend not to adhere to the periosteum of exposed, irradiated ribs. Pedicled muscle flaps provide a reasonable option to act as an interface between the irradiated bed and the graft. The well-vascularized muscle flap would stick to the irradiated bed, and the skin graft would adhere to the nonirradiated muscle.

For reconstructions in the anterior chest, most surgeons would choose the latissimus dorsi flap before an external oblique flap. The latissimus flap is well known and can treat the entire chest, whereas the external oblique flap covers only the lower chest. The latissimus has two significant drawbacks, however. It requires a position change that the external oblique flap does not. For large defects, the latissimus will still require a skin graft, whereas the external oblique flap to the anterior chest is better thought of as a myocutaneous flap and does not require skin grafts.

For flank defects, in many circumstances pedicled latissimus flaps or large random-pattern skin flaps can cover the irradiated site. When this is not possible, surgeons often attempt skin grafting irradiated wound beds with no exposed bone. However, in some instances a pedicled turnover external oblique muscle flap will provide an optimal nonirradiated soft tissue interface for successful closure. One example is when alloplastic material is employed for chest wall reconstruction.

Radiation Therapy After Tumor Excision
A subset of patients will undergo radiation therapy after tumor excision. In the context of this chapter, this would be more for wound sites in the breast and anterior chest than in the flank. Although a skin graft of the wound bed after tumor excision would successfully close the wound in many instances, the skin graft may not be able to withstand the subsequent radiation therapy. Full-thickness soft tissue cover would be better able to tolerate the postoperative radiation therapy than skin grafts.

The external oblique flap has advantages over the latissimus flap for chest coverage, because it provides skin to cover the defect. The latissimus dorsi muscle can carry a skin paddle, but the size of the paddle is limited based on the results of the pinch test. Because latissimus muscle flaps are typically much larger than the size of the skin paddle, skin grafts are often placed on the muscle to achieve closure, requiring a skin graft donor site and leading to poorer overall cosmesis.

Continued
The clinical examples in this chapter illustrate some of these concepts. In Fig. 10C-9, an alloplast of the flank is covered with an external oblique turnover flap, and the cover for the flap is mobilized chest skin. The other examples in the chapter illustrate the ability of external oblique pedicled flaps to cover large anterior chest wounds with full-thickness flaps, without skin grafts.

Anatomic Considerations
The external oblique myocutaneous flap performed in V-Y fashion moves like other segmentally vascularized flaps. The external oblique muscle slips have a particular orientation, classically described by medical students as the “hands in the front pockets” direction. The anterior abdominal skin is elevated off of the anterior rectus fascia to the level of the semilunar line. Then, analogous to the components separation procedure, the external oblique aponeurosis is incised, and the deep aspect of the muscle is elevated to the midaxillary line, where the segmental perforators enter the muscle. The perforators are small, and are not dissected into the internal oblique. Rather, the orientation of the muscle changes from approximately 45 degrees sloping downward to 45 degrees pointing upward. This allows the skin located distal to the muscle to have a much greater arc of movement superiorly for closure of lower chest defects. Further advancement superiorly can be obtained with a backcut of the muscle, which is done sparingly. The external oblique flap does not advance well anteriorly or inferiorly, because the orientation of the muscle is not markedly changed in these directions.

The segmental perforators enter the muscle at the midaxillary line, along a curved rather than straight line (Fig. 10C-17). The upper slips of the muscle cause the perforators to enter along the anterior axillary line, rather than at the midaxillary line. Therefore for turnover flaps the upper perforators must be divided where the muscle is in contact with the rib cage. This can potentially cause some relative ischemia of this aspect of the muscle.

For turnover flaps to the back, the muscle can reach the posterior midline, but it is fascia rather than muscle that reaches this location (Fig. 10C-18). Because this would be the most distal part of the flap, it may not be prudent to use the external oblique turnover flap to attempt to cover spinal instrumentation.
Personal Experience and Insights
The external oblique muscle is commonly released in the components separation hernia repair. Based on my observations after performing hundreds of these procedures, the loss of function of the external oblique is truly negligible. Rarely, hernias occur at the level of the semilunar line. These are often associated with a release that injures the internal oblique fibers inadvertently. The shape of the abdomen changes with release of this muscle, and this can be seen and measured on CT scans. This should be discussed with patients preoperatively; however, reconstruction of irradiated tumor sites is a priority over cosmesis when making decisions.

A downside of the pedicled myocutaneous flap performed in V-Y fashion is that the upper aspect of the flap is next to the tumor and could be irradiated or marginal in quality. Elevating the flap causes a large potential space that must be addressed in the operating room with multiple drains and quilting sutures. During the final inset, care is taken not to place tension on the superior (and potentially most ischemic) part of the flap.

A downside of the turnover flap is that most of the abdominal skin will require elevation to harvest the flap. Maintaining periumbilical perforators from the rectus muscle is important to prevent ischemic necrosis of the donor site skin.

Recommendations
I recommend the external oblique myocutaneous flap for lower chest lesions when radiation has been or will be given, and when thoracodorsal artery–based flaps (latissimus flap and thoracodorsal artery perforator flaps) are unavailable. A large backcut in the lower abdominal skin will ensure good superior movement, and this is best closed in V-Y fashion. The external oblique muscle turnover flap should be used in irradiated nonmidline back and flank defects when latissimus and large skin flaps are not available or not of good quality. Perforators leaving the chest wall along the anterior axillary line and traveling to the superior slips of muscle may need to be sacrificed for optimal movement.

Postoperative Care
External oblique flaps do not require any special postoperative precautions. For large back defects, pressure relief beds should be ordered so that the patient can lie on and compress the flaps against the wound bed.

EXPERT COMMENTARY
Michael R. Zenn

Advantages and Limitations
The external oblique flap is one of the best-kept secrets in chest wall reconstruction. For most chest wall needs, one commonly sees latissimus flaps, or for larger tissue needs, the vertically oriented VRAM flap. One common problem in these cases is that the blood supply to the flap may have been divided during resection of the tumor, or chest wall irradiation may affect the quality of perfusion to those flaps. The latissimus dorsi may be further complicated by previous lymph node dissection and lymphedema of the arm on the same side.

Enter the external oblique flap, with abundant tissue and a robust blood supply unaffected by surgical resection and chest wall irradiation. It is easy to raise the flap with remarkably low morbidity. The external oblique is the flap of choice in my practice for lower third chest wall defects.
Recommendations

Planning
The external oblique flap works well because it uses the circumferential excess of the abdomen to harvest the flap while still allowing primary closure of the donor site. For very large defects, I combine the VRAM and the external oblique flaps and still achieve primary closure in the abdomen (see Figs. 10C-13 and 10C-14). Only once in my practice have I needed to skin graft the donor site.

Technique
Most reconstructive surgeons who perform component separation of the abdominal wall are already performing an external oblique flap. The only missing piece is release of the muscle superiorly and the cutback of the lower flap to allow advancement.

The flap is elevated, and the dissection is performed up to the intercostal neurovascular bundles, preserving them (Fig. 10C-19). Release of the inferior muscle will divide some of the vascular contributions of the DCIA, but this division is necessary for flap rotation. As many of the intercostal bundles as possible should be maintained and this ultimately limits flap advancement. Although Bogossian et al stated that the flap could reach the upper third of the chest and clavicle, I feel this requires too much sacrifice of the segmental blood supply, and I limit the use of the flap to lower third defects only.

Take-Away Messages
Two pearls that I can pass on after performing this flap for many years regard design of the external oblique flap. First, one should not cross the midline with the flap design. The upper abdomen has less cross-perfusion than the lower abdomen, and tissues carried across the midline do not survive well. Cases in which a previous midline incision exists are perfect for the external oblique flap, since the tissues have been partially “delayed.”

Second, it is not necessary to carry tissue below the umbilicus, so the flap design should encompass a gentle curve from just above the umbilicus to just above the ASIS. This is where the donor site can be “cheated” closed, using horizontal laxity. The most important reason to design the flap this way is that it prevents the umbilicus from being distorted and pulled to the side.

The biggest surprise in using this flap is how well patients tolerate the procedure. Analgnesia requirements are much lower than with alternative flaps. There are no hernia issues, so once the drains have been removed, there are few restrictions and patients can more quickly resume their normal activities.
**Bibliography With Key Annotations**

**Anatomic Series**


This study documented the extent of the arteries supplying the external and internal oblique muscles and the connections among the vascular territories. Ten adult human cadavers underwent whole-body arterial perfusion (200 ml/kg) with a mixture of lead oxide, gelatin, and water, through the carotid artery. The external and internal oblique muscles were dissected and subjected to radiography. The vasculature of each muscle was analyzed by using the paper template technique. The areas of the vascular territories of the individual intercostal arteries within the external oblique muscle varied from 9% to 22%. The area of the vascular territory of the muscular branch of the deep circumflex iliac artery was 5% to 18%. The ascending branch of the deep circumflex iliac artery supplied a mean of 35.7% of the vascular territory of the internal oblique muscle. The lower six posterior intercostal arteries supplied a mean of 48.5%; the lateral branches of the deep inferior epigastric artery supplied a mean of 15.8%. This information provides the basis for the design of external and internal oblique muscle flaps for functional muscle transfer.

**Clinical Series**

*Abdominal Wall Coverage*


This article focuses on “separation of parts hernia repair,” a technique for repairing massive ventral hernias complicated by the “loss of domain.” Separating parts reverses domain loss by increasing intraabdominal volume; however, because the hemidiaphragms are not raised into the thoracic cavity, pulmonary complications are minimal. The authors reviewed charts of 102 patients treated by a single surgeon. All patients had postoperative pulmonary complications. Ten patients had matching preoperative and postoperative abdominal CT scans that were computer analyzed for intraabdominal volume changes and diaphragm height measurements. Intraabdominal volume increased from 8600 ± 2800 ml to 9700 ± 2700 ml. The change in diaphragm height was not statistically significant. The authors concluded that the separation of parts technique effectively closed large ventral hernias without a high incidence of pulmonary complications.


This is the paper credited with launching the current popularity of component separation in the repair of abdominal wall hernias. The authors presented a detailed approach to the technique as well as its outcomes. This paper is essential reading for any surgeon interested in repairing these problematic defects.


The authors reported their experience 1985 to 1990 in 33 patients who underwent breast reconstruction with bilateral lower rectus abdominis flaps. Bilateral external oblique flaps were used for reconstruction of the abdominal wall. These were advancement flaps of external oblique muscle and fascia. The external oblique flaps were performed only if the rectus sheath could not be approximated without tearing. Of the 33 patients, seven required mesh overlay because the repairs were excessively tight. Thirty-two patients healed uneventfully with satisfactory abdominal wall integrity. One patient developed a postoperative hernia.
Breast Reconstruction

A turnover flap of external oblique muscle and anterior rectus sheath is described. This is a useful flap to provide muscle coverage inferiorly below the pectoralis in breast reconstruction. The authors reported their experience with 11 patients. In addition to the muscle flap, they advocated a bipedicled abdominal skin flap for skin coverage over the muscle.


The ipsilateral lower abdominal skin ellipse is elevated as a myocutaneous flap including the external oblique and then transposed to the breast for autologous breast reconstruction. The authors reported their experience with five patients. One failure resulted from compression in a subcutaneous tunnel.

Chest Wall Coverage

Defects resulting from resection of advanced breast tumors can be quite large, posing a difficult reconstructive challenge. A significant number of such patients present with local recurrences after receiving external beam radiation and/or chemotherapy treatments. Pectoralis major, latissimus dorsi, rectus abdominis, and omental flaps with split-thickness skin grafts have been recommended for closure of chest wall defects. What is often excluded from the list of reconstructive options is the external oblique myocutaneous flap. In this series of 20 consecutive patients treated at Memorial Sloan-Kettering Cancer Center, an external oblique myocutaneous flap was used to cover these large chest-wall defects successfully. Sixty-eight percent of patients presented with a local recurrence: 50% had external beam radiation, and 50% had received chemotherapy; 25% of the study group had had both treatments. The authors stated that the external oblique myocutaneous flap should be considered a safe and reliable option when reconstruction of large chest-wall defects is contemplated.


These authors were the first to demonstrate that a large chest wall defect could be closed with an external oblique myocutaneous flap.


This study focused on repair of abdominal wall bulges following the various forms of TRAM flap reconstruction, whether pedicled or free. Ten patients were identified as having abdominal wall contour abnormalities after a TRAM flap and underwent an extended Prolene mesh repair with external oblique muscle reinforcement. The mesh was secured to the bony landmarks of the lower abdomen and the abdominal wall fascia. All patients achieved complete resolution of abdominal wall bulging. In the follow-up period, no recurrences, infections, or seromas were noted. One patient, who failed an earlier repair at the inferior abdominal wall, reported symptoms consistent with a scar neuroma. Symptoms were treated successfully with gabapentin and a nonsteroidal antiinflammatory drug.


The authors presented the external oblique flap as a free flap. Anatomic studies were performed in 35 human cadavers. In addition to the segmental arteries, one or two large branches of the deep circumflex iliac artery contributed significantly to the blood supply of the external oblique muscle in 33 of the 35 cadavers. Based on these findings, the authors transplanted the external oblique muscle
Abdomen

• 10C: External Oblique Flap

successfully as a free flap based on the deep circumflex iliac vessels in six patients. The muscle flap is thin, pliable, and can be combined with an iliac bone or an abdominal skin transplant. Its vascular pedicle is long (mean 12 cm) and of adequate diameter for microvascular repair. The donor scar of the flap is inconspicuously situated along the inguinal ligament and the iliac crest.


A new extended external oblique myocutaneous flap used in the reconstruction of chest wall defects, is described as a V-Y rotation flap on the ipsilateral abdominal wall. The flap is described as incorporating the anterior leaflets of the rectus sheath. This flap was used in 13 patients with major anterior chest wall excisional defects. The mean chest wall defect was about 390 cm². Marginal necrosis was observed in one patient. All other flaps healed without complications. The extended external oblique myocutaneous flap differs from other external oblique flaps already described in several aspects that allow it to obtain better functional and aesthetic results.


This retrospective institutional study reviewed 10 years of myofascial flap reconstruction from 1996 to 2006 at Thomas Jefferson University Hospital and revealed an 18.3% recurrence rate in 545 component separations. From this vast experience, the authors identified obesity (BMI greater than 30 kg/m²), age older than 65 years, males, and the presence of postoperative seroma and preoperative infection as risk factors for hernia recurrence.

Elbow Coverage


The author described a fasciocutaneous flap based on myocutaneous perforators from the external oblique muscle into the overlying skin. The flap is based posterolaterally in the posterior axillary line. The flap is well suited for coverage of elbow defects. The author reported five patients in whom the flap was successfully used for elbow coverage with no flap loss. In fact, the only complication was an infected donor site. The anatomy and blood supply of the flap are clearly illustrated through cadaver injection studies.

Lumbosacral Coverage


In this case report the authors reconstructed a large radiation ulcer of the lumbosacral area with a very long external oblique myocutaneous flap. The flap successfully covered the radiation ulcer, and there were no complications. This innovative application of the external oblique musculocutaneous flap solved a difficult reconstructive problem in the lumbosacral area.

Pelvic Defects


The authors demonstrated that this large flap can easily be transposed superiorly for coverage of defects of the chest wall. However, they also demonstrated that the flap can easily be transposed inferiorly for coverage of extensive defects. In a patient undergoing a hemipelvectomy, the resultant defect was satisfactorily covered with a large external oblique myocutaneous flap.
ANATOMIC LANDMARKS

Landmarks  Lower abdomen; variable across midline.
Size  $30 \times 15$ cm.
Composition  Fasciocutaneous.
Dominant Pedicle  Superficial inferior epigastric vessels.
Nerve Supply  *Sensory*: Segmental intercostal nerves T10 to T12.
Section 10D

ABDOMEN

Superficial Inferior Epigastric Artery (SIEA) Flap

CLINICAL APPLICATIONS

Regional Use
- Abdomen
- Groin and perineum

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Penile reconstruction
- Vaginal reconstruction
- Breast reconstruction
ANATOMY OF THE SUPERFICIAL INFERIOR EPIGASTRIC ARTERY (SIEA) FLAP

Fig. 10D-1

Dominant pedicle: Superficial inferior epigastric artery and vein
ANATOMY

Landmarks
The SIEA flap is a fasciocutaneous flap incorporating the lower abdominal skin between the umbilicus and pubis. Vertical or transversely oriented flaps of the lower abdominal skin may be based on the SIEA. Vertical flaps may extend up to the costal margin and horizontal flaps extend from the ipsilateral anterior superior iliac spine to the midline, with less-predictable flow across the midline.

Composition
Fasciocutaneous.

Size
30 × 15 cm.

Arterial Anatomy (Type I)

Dominant Pedicle
Superficial inferior epigastric vessels
This vessel is not consistent and is absent in up to 15% of individuals. Its caliber is highly variable, rendering it clinically unusable in many patients. Using the flap in the face of small-caliber vessels increases the risk of fat necrosis and flap loss. The venous drainage is through the venae comitantes with the SIEA or through the superficial inferior epigastric vein (SIEV), which is a large, more medially and superficially located vein; it is vertically oriented and drains the lower abdomen. This vein is more superficially located than the SIEA.

LENGTH 4 to 6 cm.
DIAMETER 1 to 1.5 mm.
LOCATION The SIEA originates from the anterior surface of the femoral artery 4 to 5 cm below the inguinal ligament. In as many as 48% of cases, it may arise from a common trunk with the superficial circumflex iliac artery (SCIA). It courses vertically upward, crossing the inguinal ligament at a point halfway between the anterior superior iliac spine and the pubis. It courses deep to Scarpa’s fascia.

Venous Anatomy
Single or duplicated venae comitantes accompany the arterial circulation but often diverge from the artery above the groin, taking a more superficial course. The average venous diameter is 1 to 1.5 mm. Medially, approximately a third the distance from the pubis to the ASIS, a large SIEV is identified that can provide venous drainage to the entire flap. In some cases, this vein and the combined comitans veins join before entering the femoral system.

Nerve Supply

Sensory
Segmental intercostals T10 to T12.
Vascular Anatomy of the SIEA Flap

**Fig. 10D-2**

Dominant pedicle: Superficial inferior epigastric artery (D)

- m, Myocutaneous perforating vessels from deep inferior epigastric arcade
- p, pubis
- s, segmental subcostal arteries
- u, umbilicus
- x, xiphoid process
FLAP HARVEST

Design and Markings

The entire skin and subcutaneous tissues of the lower abdomen extending from the umbilicus to the pubis and groin crease may be based on one SIEA. Although the safe skin territory of each vessel may extend beyond the midline, most surgeons consider any cross-midline tissue to be at high risk for development of necrosis. Perfusion studies suggest that the SIEA perfuses a more lateral skin territory than does the DIEA. Typically the skin island is marked lower and more lateral than a DIEP flap or TRAM flap. The umbilicus, anterior superior iliac spine, and pubic tubercle are useful landmarks for the design and elevation of the flap. The anterior superior iliac spine and the pubic tubercle are marked, and a line is drawn between them. The midpoint of the line represents the deep origin of the vessel from the femoral artery. When the line is divided in thirds, one should look for the SIEA and vena comitans between the lateral and central third, and the medial SIEV between the central and medial third. The vessel courses vertically upward toward the costal margin. A Doppler probe may be useful for confirming the presence of the SIEA.

Patient Positioning

The patient is positioned in the supine position for flap harvest.
GUIDE TO FLAP DISSECTION
A 4 to 5 cm exploratory incision is made in the groin crease, centered on the previously marked projected location of the pedicle. Dissection is continued through the skin and subcutaneous tissues down to Scarpa’s fascia. The SIEV lies superficially within this layer and is encountered during this part of the dissection. It is identified and preserved. Dissection then continues deep to Scarpa’s fascia. Loupe magnification is recommended for this dissection. Deep to Scarpa’s fascia the SIEA is identified coursing vertically; it measures approximately 1 mm in diameter at this level. It should be noted that this vessel is not constant and is absent in 10% to 15% of patients. It is not necessary to identify the pedicle initially for local flap transposition and tubed flaps. Once the vessels are identified, they should be followed down over the inguinal ligament toward their origin from either the femoral artery or a confluence with the SCIA vessels before a combined origin from the femoral vessels. Some division of the inguinal ligament may be necessary to reach the SIEA takeoff.

Once the pedicle has been identified, the skin island is designed and elevated. Dissection of the skin island is then carried down to the abdominal wall. The external oblique and anterior rectus fascia are identified, and the flap is elevated in a plane above the external oblique fascia and anterior rectus sheath but deep to Scarpa’s fascia.
Dissection is continued to the lateral and medial DIEA perforators which should be isolated and preserved as a fallback if the SIEA proves inadequate. Once the entire flap is raised it is based on both the SIEA vessels as well as the DIEA perforator rows. These latter vessels can then be clamped with occlusive microvascular clamps to occlude their contribution to flap blood flow. If the flap remains well perfused, it can be assumed that the flap can be safely based on the SIEA vasculature. If the flap becomes congested or extremely pale with DIEA occlusion, the flap should be raised as a DIEP flap, preserving the SIEV as an alternative venous outflow in case congestion supervenes. Assuming the SIEA inflow is adequate, the flap is raised as a SIEA flap, dividing the DIEA perforators to leave the flap dependant only on its SIEA circulation. If a SIEV is present medially, it too should be dissected down to the femoral vein and be clipped for possible additional venous anastomosis.

At this juncture, laser-induced indocyanine green fluorescence imaging (SPY, LifeCell Corp., Branchburg, NJ) is helpful for assessing the exact extent to which skin may safely be preserved within the flap. Once a well-perfused skin island is ready for transfer, the vascular pedicle can be divided and the flap transferred to its recipient site for anastomosis.

**Extension of Pedicle Length**
Dissection of the vascular pedicle toward its femoral artery origin will significantly increase the length of the pedicle and the diameter of the vessels dissected. This dissection is performed under loupe magnification and is only necessary for microsurgical transfer. The superficial inferior epigastric vein is traced to the saphenous or femoral vein to increase pedicle length.
FLAP VARIANT

Pedicle Flap
One can take advantage of the donor site locally by using the flap as a pedicle flap. Often the flaps are more vertically oriented, because a rotated flap can reach the groin, perineum, or abdomen. These flaps have been described for penile and vaginal reconstruction. Because of its anatomic variability, the SIEA is usually a tertiary choice as a pedicle flap, since SCIA, DIEA, and proximal thigh flaps are more reliable.

ARC OF ROTATION
The vertical flap is transposed to the trochanter or perineum. The pedicle at the level of the inguinal ligament becomes the point of rotation.

FLAP TRANSFER
The vertical flap is transposed into the defect or through a subcutaneous tunnel. Care must be taken not to kink or compress the pedicle.

FLAP INSET
The flap may safely be trimmed deep to Scarpa’s fascia as required to reduce bulk. The flap is sutured directly into the defect without tension. Compared with the TRAM or DIEP flaps, no muscle or fascia exists to secure the flap at its recipient site. Often only the skin closure provides support.

DONOR SITE CLOSURE
The donor site is closed directly like an abdominoplasty when a transverse harvest is performed, whether pedicled or free. The transversely oriented flap leaves the most aesthetically acceptable donor defect. The vertical flap donor site is closed like a paramedian incision.
CLINICAL APPLICATIONS
This 45-year-old woman had undergone mastectomy without radiation. She was happy with her natural breast and asked that it be matched in her reconstruction. A TRAM flap reconstruction was selected.

Fig. 10D-6  A, The patient’s TRAM flap is marked. She had a previous lower midline incision, and it was thought that a hemiabdomen would supply enough tissue for her reconstructive needs. Although the right side was marked, no surgery was performed on that side. B, View from the right of the flap elevated. The patient had both a large superficial inferior epigastric system (1.7 mm artery at its origin) and some large DIEP perforators near the umbilicus, both the lateral and medial rows. The DIEP perforators were clamped and the blood flow from the SIEA evaluated. C, The SIEA flap elevated, with good pedicle length. All tissue appeared well perfused before division. D, One-year postoperative view. No revisions were required, and no symmetry procedures were performed on the right. Nipple reconstruction was done with nipple sharing and tattooing. E, Oblique view, 1 year postoperatively. (Case supplied by MRZ.)
This 52-year-old diabetic woman with a mastectomy deformity had undergone radiation therapy to the chest wall. Six months after radiation therapy was complete, she presented for right breast reconstruction, for which her generous abdominal pannus was used. She is happy with her current left breast size and has no plans to lose weight intentionally.

Fig. 10D-7  A, The patient’s pannus was marked preoperatively and was explored for vessels. Most of the pannus was discarded. B, A large superficial inferior epigastric artery (1.5 mm at its origin) and two accompanying veins were found. C, Closeup of SIEA and SIEV. The artery and vein accompanying the artery are deep. A more medial second superficial vein, seen here engorged, is often harvested with the flap for additional venous drainage. D, Six-month follow-up photo. The patient did not require any revision of the right reconstruction but did have a left mastopexy for better symmetry. E and F, Left and right oblique views. (Case supplied by MRZ.)
This 43-year-old woman, who had previously undergone gastric bypass surgery, presented with this mastectomy deformity with no history of chest wall irradiation. She had a preliminary left breast reduction while waiting for her weight to stabilize so as to have a target breast to match. She had a lower midline scar, and it was felt that there was enough tissue in her hemiabdomen to perform her reconstruction.

Fig. 10D-8  A, Preoperative markings. B, The patient is seen at her 1 1/2-year follow-up. She had a small SIEA (1.2 mm diameter at its origin). The anastomosis was end-to-end to a second intercostal perforator. Two superficial veins were anastomosed as well. She did not require any revisions. Nipple reconstruction was with nipple sharing; the photo was taken on the day of her areolar tattoo. C and D, Right and left oblique views. (Case supplied by MRZ.)
This 46-year-old woman had previous bilateral mastectomies without radiation and presented for delayed bilateral breast reconstruction using her abdominal tissues.

Fig. 10D-9  A, The patient’s preoperative markings are shown. On exploration of the left side of her abdomen, she had a significant SIEA (1.1 mm) and SIEV (2.5 mm), but only significant DIEPs on the right. B, She is seen at 10-month follow-up. An SIEA flap was placed on the left, anastomosed to the internal mammary artery end-to-side because of vessel mismatch. The right was reconstructed with a three-perforator DIEP. She did undergo a small touch-up procedure at 4 months consisting of some liposuction and skin reshaping, with revision of some of her abdominal scars. Her nipple reconstructions are star flaps with three-dimensional tattoos. C and D, Right and left oblique views. (Case supplied by MRZ.)
This woman presented with left breast ductal carcinoma in situ and wished to have autologous reconstruction. Because of the small volume of her abdominal tissue, a bipedicled flap was planned. On one side a DIEP flap was designed, and on the contralateral a SIEA flap was designed that was then to be connected to a branch of the DIEP medial row perforator. Using the entire abdominal flap allowed a volume match with the right breast.

Fig. 10D-10  A, The patient is seen preoperatively. B, A DIEP and an SIEA flap were designed and marked. C, Flap and donor site. D, Flap (DIEP and SIEA). E, The results are seen postoperatively. (Case courtesy Aldona J. Spiegel, MD.)
This patient presented with a right-sided breast malignancy and wished to undergo a contralateral prophylactic mastectomy. She had adequately sized SIEA diameters on both sides and therefore was able to undergo immediate reconstruction with bilateral SIEA flaps.

Fig. 10D-11  A, The patient is seen preoperatively. B, Preoperative markings for SIEA flaps. C, Intraoperative views of the left SIEA flap and D, the right SIEA flap. E, The results are seen postoperatively. (Case courtesy Aldona J. Spiegel, MD.)
**Pearls and Pitfalls**

- The SIEA is not a constant vessel; it may be absent in 10% to 15% of patients. Furthermore, when present, it is usable only 10% to 15% of the time.
- Extension of the transversely oriented skin island beyond the lateral margin of the opposite rectus abdominis is not reliable and may lead to loss of the flap or subcutaneous tissue. When tissue is required beyond the midline, delay should be considered.
- It is considered unsafe to perform the flap if the SIEA has a caliber of less than 1.5 mm, because the risk of fat necrosis and flap thrombosis increase twofold to threefold at smaller vessel calibers.
- The flap deep to Scarpa’s fascia can be safely trimmed, except adjacent to the vascular pedicle.
- With SIEA free flaps the surgeon must be prepared for a vessel mismatch, and appropriately sized recipient vessels should be sought.

**EXPERT COMMENTARY**

Aldona J. Spiegel

**Indications**

The SIEA flap is indicated in patients with sufficient excess abdominal tissue who require reconstruction of a soft tissue defect by either free tissue transfer or pedicled reconstruction of pelvic defects.

**Advantages and Limitations**

The main advantage of the SIEA flap is that it provides all of the benefits of the traditional lower abdominal tissue flaps without incision or excision of the abdominal wall fascia or musculature, thereby decreasing donor site morbidity.

The SIEA flap is limited mainly by the anatomic variability of its blood supply. Since the SIEA is not present in every patient, use of this flap is not always possible. Additionally, even if the SIEA is identified, it may not be of sufficient caliber for free flap transfer. We require the SIEA to have a 1.5 mm or greater diameter, and it must have a visible and palpable pulsation for free flap transfer. Once these criteria are met for free flap transfer, there may still be a constraint by size mismatch with the recipient vessels. Finally, pedicled SIEA flaps are limited by the length of the pedicle.

**Anatomic Considerations**

In a study by Taylor and Daniel1 of its anatomic variation, the SIEA was found to be absent in 35% of their subjects. In the patients who had an SIEA flap reconstruction, the origins of the SIEA were varied, with 48% sharing a common trunk with the superficial circumflex artery, whereas 17% were found to be direct branches of the common femoral artery. Our clinical experience corroborated these findings,2 showing a lack of an identifiable SIEA in 42% of our 278 total patients. Further investigation of the other 58% of patients with an identifiable SIEA showed that 54% of these patients had arteries with external diameters of 1.5 mm or greater when measured at the level of the lower abdominal incision.

Continued
This is important because our selection criteria for the SIEA flap requires such a diameter. Therefore only 31% of all patients in our study had an SIEA sufficient for use in a free flap.

**Personal Experiences and Insights**

As mentioned, the main limitation of the SIEA flap is the inconsistent anatomy and size of the arterial inflow. However, the venous outflow of this flap is excellent: there are two pathways, the SIEV and the venae comitantes of the SIEA. This is in contrast to the DIEP flap, where the most common limitation is the venous outflow, which may lead to congestion. Therefore, when considering transfer of the lower abdominal tissue, the surgeon must make intraoperative decisions about the reliability of the arterial and venous anatomy once the sizes of the vessels are assessed. It may be helpful to use vascular clamps in situ during flap harvest to determine which vessels will be more reliable.

**Recommendations**

**Planning**

When marking the flap location on the abdomen, it is important to consider the location of the inferior abdominal incision—the lower it is, the more likely that the arterial caliber of the SIEA will be larger as it enters the flap. Because of limited abdominal laxity, this will also require the top abdominal incision to be more inferior, either at the umbilicus or below, which may not be optimal for the DIEP flap, since it may not capture the larger periumbilical perforators. Therefore the surgeon must strike a balance between making the flap location as low as possible on the abdomen for the SIEA flap, while still capturing the appropriate perforators should a DIEP flap be required if an SIEA flap is not possible.

**Technique**

Dissection of the SIEA flap is fairly simple compared with dissection of the perforator flaps. The microsurgical challenge usually presents itself at the point of anastomosis, because there is usually some component of vessel size mismatch with the recipient vessels. One must not completely skeletonize the vessels as they are dissected in the groin, because they are small and may be prone to kinking if there is not enough surrounding tissue to support the vessels after inset. In addition, only a small amount of tissue should be left around the vessels, since this requires transection of lymphatics, which may lead to increased seroma formation.

There are two choices for venous outflow; we usually choose the venae comitantes and dissect them proximal to the point at which they unite to become one vein. We prefer this vein to the larger SIEV, because it is close to the artery and usually the same length; therefore the chance for kinking or twisting of the small artery is minimized. Although the SIEV is usually larger, it is usually at a distance from the artery and may not have a similar length, which may potentially create a tethering point.

**Postoperative Care**

When the flap is used for breast reconstruction, the patient is sent to the ICU for hourly monitoring of the transplanted flap. On postoperative day 1, the patient is advanced to a reclining chair for a 1-hour sitting trial. Because of the gravitational changes on the flap, nurses are instructed to closely monitor the flap for any change in Doppler signal, capillary refill, and skin color. If the patient has a successful sitting trial, she will slowly begin ambulating, as tolerated, and usually can be discharged on postoperative day 3 or 4.

For anticoagulation therapy after surgery, we use low–molecular–weight heparin, monitored with thromboelastogram viscoelastic testing. Beginning on postoperative day 1, the patient is placed on a daily regimen of 81 mg “baby” aspirin for 2 weeks.
Complications
Apart from anatomic arterial limitations, the most common problem is the possibility of developing a seroma at the abdominal donor site. This occurs mainly as a result of lymphatic leakage from tissue that is transected in the lower abdomen during the dissection of the SIEA pedicle. A helpful tip is to clip the surrounding lymphatics during dissection. We also use two drains and leave them in until there is less than 25 ml per drain per day. This strategy has decreased seroma formation to less than 0.5% in our patient population.

Take-Away Messages
The SIEA flap is very useful for reconstruction of skin and soft tissue defects; its use avoids transection of fascia or muscle in the lower abdomen. However, one must be cautious during the intraoperative selection process, by critically assessing the arterial inflow and not being lured by the ease of flap harvest.

References

EXPERT COMMENTARY
Michael R. Zenn

Advantages and Limitations
The SIEA flap is both the most desirable and the least available of lower abdominal flaps. It is desirable because it allows harvest of the lower abdominal tissues without violation of the abdominal fascia, avoiding most of the morbidity that comes with harvest of the lower abdomen as a TRAM or DIEP flap. It is the least available, because appropriate vascular anatomy is present only 5% to 10% of the time. Even then, it is a question of how comfortable one feels about using a flap with a 1 to 1.5 mm diameter artery.

Recommendations
Planning
With some important caveats in mind, one can use the SIEA flap with much success:
• Always look for the superficial pedicle laterally and the more prominent medial vein. If you do not use them as your primary vessels, take them with the flap as backups or secondary anastomoses. Practice makes perfect.
• Since the vessel is more laterally based, alter the skin design to favor the lateral tissues over tissues that lie across the midline.
• Look for an artery that is 1.5 mm or larger at its femoral source. There also should be a visible pulse in the artery as it enters the flap.

Continued
• Get comfortable with smaller anastomoses, especially end-to-side (internal mammary artery), perforator-to-perforator (second intercostal perforator), and smaller vessels that are a better match for end-to-end (serratus branch of the thoracodorsal artery).
• A lower midline scar may have a “delay” effect on the SIE system.
• A previous Pfannenstiel incision does not preclude the use of an SIEA flap, because the pedicle can be quite lateral.

Perhaps the greatest use of the SIEA system in my practice comes when it can be used to augment a DIEP or free TRAM flap, when all abdominal tissues are needed and blood supply across the midline is not robust. Even a small vessel can be easily connected to the contralateral DIE pedicle and needed perfusion can be added to the flap without another fascial incision.

Fig. 10D-12  The SIEA and SIEV (right arrow) have been connected to the contralateral DIEA and DIEV (bottom arrow) so that the entire flap can be vascularized on one anastomosis.

**Take-Away Messages**

My final word of advice is to treat the abdomen as you would for an abdominoplasty, making the patient just as pleased about the donor site as the recipient site. In some early cases, I was so happy to find a large SIEA to carry the flap that I did not plicate the abdomen as I would have if the patient presented for abdominoplasty. Most patients appreciate a flat abdomen when possible.
Bibliography With Key Annotations

Clinical Studies


Breast reconstruction using flaps from the lower abdomen can be compromised by fat necrosis. The muscle-sparing free transverse rectus abdominis myocutaneous (TRAM), deep inferior epigastric perforator (DIEP), and superficial inferior epigastric artery (SIEA) flaps are techniques that have evolved in an effort to decrease abdominal donor site morbidity. Each flap in this evolution, however, includes fewer perforating blood vessels. The authors hypothesized that flaps with fewer perforators are less well perfused and therefore more likely to suffer fat necrosis. They prospectively studied the incidence of fat necrosis and number of perforators in 228 consecutive abdominal free flap breast reconstructions. The incidence of fat necrosis was 14%, 25%, 5%, and 19% for SIEA flaps and flaps with one to two, three to five, and more than five perforators, respectively. The incidence of fat necrosis was significantly associated with the number of perforators, smoking, and inclusion of zone 3 of flaps. The lowest risk of fat necrosis occurred in flaps with three to five perforators, which were predominantly muscle-sparing TRAM flaps. The risk of fat necrosis was highest in flaps with one or two perforators, which were predominantly DIEP flaps. SIEA flaps and flaps with poor perforators in which more than five perforators were included had an intermediate risk of fat necrosis.


Autologous abdominal breast reconstructions are favored by many reconstructive surgeons. High success rate and cost-effectiveness are two important factors that may guide decision-making in the management plan. The authors compared the resource costs and success rates of immediate and delayed breast reconstructions using either DIEP or SIEA flaps. The resource cost is referred to as the cost of operation and hospitalization. During a 12-month period, 42 patients underwent immediate (21) or delayed (21) unilateral breast reconstruction using either a DIEP (30) or SIEA (12) flap by one surgeon. There were no statistical differences in resource costs, success, and complication rates between DIEP and SIEA flaps in both the immediate and delayed breast reconstruction groups.


After the TRAM and the DIEP, the SIEA flap is the next logical step to reduce donor site morbidity in autologous breast reconstruction. However, the vascular axis of the SIEA flap is completely different from the deep epigastric pedicle on which previous lower abdominal flaps were based. Therefore mapping the vascular territory that can be reliably harvested on this pedicle seems mandatory before this new technique can become established. The authors reported their clinical prospective study of 10 patients undergoing autologous breast reconstruction to chart the angiosome of the superficial inferior epigastric artery with regard to breast reconstruction and to evaluate the random extension of the vascular territory that can be reliably raised on this pedicle. They found that the true angiosome of the superficial epigastric artery is located laterally on the ipsilateral hemiabdomen. Its random extension is unreliable and ranges most frequently only to the midline. Based on the results of this study, survival of the skin and subcutaneous fat taken laterally to the border of the contralateral rectus sheath seems questionable. Therefore the versatility of the SIEA flap for autologous breast reconstruction seems limited when compared with the conventional methods based on the deep inferior epigastric system.

Reconstruction of head and neck defects may require replacement of the bony structures, external soft tissue, and intramucosal mucosa. Most cases, including maxillary defects, often require repair using only soft tissue flaps. The authors used free superficial circumflex iliac artery/superficial inferior epigastric (SCIA/SIEA) flaps for head and neck reconstruction. This was their first choice over other free flaps because of its versatile advantages. Fifteen patients underwent head and neck reconstruction with free SCIA/SIEA flaps. No flap loss was observed; however, emergency vascular reanastomosis was performed in three cases to restore the blood supply in compromised flaps. Flap thinning and secondary debulking procedures were performed in four cases. The functional and aesthetic results were deemed acceptable in all patients. Based on their results, we stated that the free SCIA/SIEA flap is useful for soft tissue defect reconstruction in the head and neck. It has the following advantages: large flap elevation is possible for reaching distant recipient vessels, two surgical teams may work at the same time preparing the donor and recipient regions, and the flap design uses an abdominoplasty incision, which has minimal donor site morbidity.


The purpose of this study was to demonstrate the impact of bilateral free flap breast reconstruction on the abdominal wall. The authors compared bilateral combinations of the muscle-sparing free TRAM flap, DIEP flap, and SIEA flap. A blinded prospective cohort study was performed involving 234 patients. Patients were evaluated preoperatively and for 1 year postoperatively. At each visit, patients underwent objective abdominal strength testing using the Manual Muscle Function Test and Functional Independence Measure and psychometric testing using the SF-36 questionnaire. At postoperative visits, patients also completed a questionnaire specific to breast reconstruction. Statistical analysis included the Kruskal-Wallis, Mann-Whitney, Friedman, and Wilcoxon signed rank tests. Of 234 patients enrolled, 157 underwent reconstruction, 82 of which were bilateral. There was a significant decline in upper and lower abdominal strength from bilateral free TRAM flaps compared with bilateral DIEP flaps. Likewise, there was a significant decline in upper and lower abdominal strength from bilateral free TRAM flaps compared with bilateral SIEA flaps. For combinations, the most muscle impairment to least was as follows: free TRAM/free TRAM, free TRAM/DIEP, DIEP/DIEP, DIEP/SIEA, and SIEA/SIEA. The free TRAM/SIEA data were not significant. Although psychometric testing showed trends, there was no significant difference among treatment groups. The authors concluded that abdominal wall strength following various combinations of bilateral free flap breast reconstruction techniques closely adheres to theoretical predictions based on the degree of surgical muscle sacrifice.


Attempts to limit the impact of autologous breast reconstruction on the abdominal wall have led to the use of the muscle-sparing free TRAM, DIEP, and SIEA flaps. The authors compared the SIEA flap with the muscle-sparing free TRAM flap to determine whether gains in abdominal wall function are offset by flap-related complications. Seventy-two consecutive SIEA flaps were compared with 369 consecutive muscle-sparing free TRAM flaps. Outcomes included arterial and venous thrombosis, reoperation, abdominal hernia/bulge, seroma, hematoma, fat necrosis, delayed wound healing, infection, partial flap loss, and total flap loss. Chi-square and Fisher’s exact tests were used to determine significant differences. In the SIEA group, there was a higher percentage of overweight patients, bilateral cases, and smokers. Among SIEA flaps, there were two total flap losses (2.9%) and no abdominal morbidity. In the muscle-sparing free TRAM flap group, there was one total flap loss (0.18%), and a hernia/bulge rate of 1.9%. The difference in flap loss rate was significant.
was a higher incidence of vessel thrombosis requiring anastomotic revision in the SIEA group: 17.4% compared with the free TRAM group, 6.0%. The authors concluded that the SIEA flap has a lower rate of hernia/bulge and a higher rate of thrombotic complications. Because of the emotional and financial cost of these complications, the SIEA flap should be undertaken only if strict criteria are met.


This retrospective study was conducted to assess the reliability and examine the outcomes of SIEA flaps for breast reconstruction while considering an intraoperative algorithm established in this study. Ninety-nine SIEA flap reconstructions were performed in 82 patients in a 3½-year period. Patients were divided into two groups (before and after algorithm implementation), and their medical records were evaluated with respect to demographic information, tumor type, tobacco use, ischemic time, flap weight, and complications. Potential risk factors for complications were also assessed. Only smoking at the time of surgery was associated with increased donor site complications. The authors concluded that their intraoperative algorithm helped decrease flap and abdominal complication rates for the SIEA flap.

Anatomic/Experimental Studies


This was the first report of microvascular free flap transfer of the SIEA flap, which the authors referred to as the “superficial epigastric artery flap.” Their experience with 10 free flaps between 1973 and 1976 was presented. Nine of the 10 flaps were harvested from the lower groin-abdominal area based on the superficial epigastric artery (3 patients), superficial circumflex iliac artery (3 patients), or both via a common trunk (3 patients). Because of the variation in size and anatomy of the vessels the authors started with a 5 cm groin incision and exposed the origin of the superficial inferior epigastric artery and superficial circumflex iliac artery from the femoral artery or the common trunk if both vessels arise from a common trunk. The largest vessel was selected and cannulated with a Teflon catheter and 2 ml of patent-blue V dye was injected into the artery. The skin territory of the vessels and its limits immediately assumed a blue color and served as the basis for flap design. The authors stated that the dye did not damage the intima of these small vessels.


In this significant article the authors elevated large island flaps on the abdomen of dogs based on a single epigastric artery and vein. In this two-part study they not only established that flaps of significant size can be raised on a single small artery and vein, but they also demonstrated that these large islands of skin can be transferred through microsurgical techniques. They firmly established the principle of island flaps and the feasibility of the microsurgical transfer of such flaps. They commented that “it is of interest that this mass of tissue [the flap] can be maintained in a healthy, viable state by these tiny vessels.” They further stated that “the ability to create large island flaps on the lower abdomen suggests that this tissue may be rotated to supply cover for the opposite side of the abdomen, to resurface the perineum following avulsion injuries, and to restore the groin after radical inguinal resection.” All of these goals have now been achieved with the SIEA flap.


This anatomic description and clinical study demonstrated the use of this flap for coverage of surface defects of the upper extremity, including the hand, forearm, and elbow.


The anatomy and clinical applications of this flap for upper extremity coverage were demonstrated. The authors emphasized the large volume of tissue available and the acceptability of the donor site.

In this anatomic study of 100 cadaver dissections the authors reported the mean caliber of the SIEA as 1.4 mm. They found that the SIEA has a common origin with the superficial circumflex iliac artery in 48% of dissections, and the vessel is absent in 35% of dissections.

Clinical Series

This article was perhaps the first successful report of “microsurgical free flap transfer.” Antia and Buch transferred the dermis-fat flap from the lower abdomen based on the SIEA vessels for facial soft tissue reconstruction. The flap vessels were harvested with a cuff of femoral artery and saphenous vein, respectively, to facilitate successful suturing to the external carotid artery and internal jugular veins.


The anatomy of the SIEA flap and its contributions to the total abdominal blood supply were well reviewed. Clinical experience with the flap for coverage of pressure sores, penile reconstruction, and microsurgical tissue transfer were presented.


This case report demonstrated the application of the SIEA flap for abdominal wall coverage. A description of the abdominal wall blood supply and interrelationship of the SIEA and perforators from the deep epigastric arcade was included.


The versatility of this flap was demonstrated. The authors used a combined superficial circumflex iliac artery and SIEA pedicle flap containing both soft tissue and a segment of the iliac crest to make an osteocutaneous flap for penile reconstruction.


This was the first report of the SIEA flap being used to correct a severe burn contracture of the forearm in an 8-year-old girl. Wood noted, “The largest and most important of these vessels are the superficial epigastric vessels proceeding from the common femoral vessel across the inguinal ligament and upwards and inwards toward the umbilicus.” He emphasized that it is “a matter of importance then to choose such a position that would leave in the base of the flap the greatest amount of blood vessels running parallel to the skin.” He believed that these vessels were the chief source of blood supply to the flap.


The use of perforator flaps in breast reconstruction has gained popularity. Although a premium has been placed on sparing muscle and fascia at the abdominal donor site, perforator flaps have less intrinsic support for the pedicle and require additional maneuvers to support the flap and secure the microvascular anastomosis. The superficial inferior epigastric artery flap in particular creates logistical problems in placement of the flap for optimal shaping while preventing kinking of its superficial and more peripheral pedicle. The author’s proposed technique secures the flap to the chest wall, maximizes flap projection, places the best vascularized tissues in proper position, and facilitates performance of the microsurgical anastomosis.
Flap Modifications


The authors presented a technique in which the unilateral lower abdominal flap is tubed and the area of the vascular pedicle is elevated as a subcutaneous pedicle. The blood supply of this flap is based on the SIEA, superficial circumflex iliac artery, and external pudendal vessels, all of which are included in the rather generous subcutaneous pedicle. The authors reported their experience with 30 consecutive patients who underwent reconstruction with this method. All flaps survived.


This paper outlined a simple approach to the SIEA flap harvest, demonstrating that favorable results may be achieved even for small caliber vessels. A total of 46 patients underwent 53 SIEA breast reconstructions over a 6-year period with a modified approach for pedicle dissection and arterial inclusion criteria solely on the basis of presence of a palpable pulse. Average pedicle length was 6.07 cm; and mean arterial (0.96 mm) and venous (2.27 mm) diameters represent the lowest published values. Three flaps (5.7%) demonstrated fat necrosis or partial flap necrosis, with one (1.9%) complete flap loss. These results compared favorably with those of previous SIEA series employing diameter-based selection criteria, suggesting that the presence of a palpable arterial pulse may be sufficient to permit successful use of this flap.


This article presented a historical review of the development of the tubed SIEA abdominal flap and acromiopectoral flaps.


Shaw described the tubing of this abdominal flap for coverage of hand, forearm, and wrist defects. The “cleanliness” of the tube was described as one of its advantages over the open flap, which Shaw had noted in his previous article on this flap.


In this retrospective review of 27 successful SIEA free flaps, the anatomy and surgical technique were described and advantages and disadvantages of this flap compared to other flaps available for soft tissue reconstruction discussed. The safety of the flap and aesthetic donor site were emphasized.
ANATOMIC LANDMARKS

Landmarks  The skin of the lateral groin may be elevated as a flap extending between the femoral vessels and the posterior iliac spine. The long axis of the flap is centered over a line parallel and 3 cm inferior to the inguinal ligament with a flap width of 6 to 10 cm.

Size  25 cm × 6 to 10 cm.

Composition  Fasciocutaneous.

Flap Type  Type A fasciocutaneous.

Dominant Pedicle  Superficial circumflex iliac artery.

Nerve Supply  Sensory: Lateral cutaneous nerve of T12.
Section 10E

ABDOMEN

Groin Flap

CLINICAL APPLICATIONS

Regional Use
- Abdominal wall
- Perineum

Distant Use
- Head and neck
- Hand, upper extremity
- Lower extremity
ANATOMY OF THE GROIN FLAP

Fig. 10E-1

Dominant pedicle: Superficial circumflex iliac artery
**ANATOMY**

**Landmarks**  The skin of the lateral groin may be elevated as a flap extending between the femoral vessels and the posterior iliac spine. The long axis of the flap is centered over a line parallel and 3 cm inferior to the inguinal ligament with a flap width of 6 to 10 cm. A simple, convenient technique for flap marking is to include 2 fingerbreadths above the inguinal ligament and 4 fingerbreadths below the inguinal ligament, the dimensions of which will easily capture a safe and well-vascularized skin flap.

**Composition**  Fasciocutaneous.

**Size**  25 cm × 6 to 10 cm. The standard flap dimensions are 10 × 25 cm, with the flap extending from the medial edge of the sartorius muscle to a variable distance 5 to 10 cm lateral to the anterior superior iliac spine. If the width of the flap is increased, direct donor site closure becomes progressively more difficult.

**Arterial Anatomy (Type A Fasciocutaneous)**

**Dominant Pedicle**  *Superficial circumflex iliac artery*

**Regional Source**  Superficial femoral artery.

**Length**  2 cm.

**Diameter**  0.8 to 1.5 mm.

**Location**  Arises from the femoral vessel deep to the deep fascia of the medial groin. The superficial branch passes over the medial border of the sartorius muscle to enter the fat of the groin. The deep branch can pass through some of the muscle bulk of the sartorius before entering the groin flap as a musculocutaneous perforator. Either vessel can support the skin island.

**Venous Anatomy**

Single veins accompanying the arterial circulation, draining to the saphenous vein; the average venous diameter is 1.5 mm.

**Nerve Supply**

**Sensory**  Lateral cutaneous nerve of T12.
**Vascular Anatomy of the Groin Flap**

**Fig. 10E-2**

**Dominant pedicle:** Superficial circumflex iliac artery (D)

s, Sartorius muscle
FLAP HARVEST

Design and Markings

The pubic tubercle and the anterior superior iliac spine are palpated and a line is drawn between these two landmarks. This line coincides with the location of the inguinal ligament. The *rule of thirds* applies to marking the borders of the flap: one third above and two thirds below the inguinal ligament. The “thirds” refers to 3 cm or 2 fingerbreadths as a measure. One third or 3 cm above the inguinal ligament and two thirds or 6 cm below the inguinal ligament demarcate the boundaries of the flap’s width. The vascular pedicle lies 3 cm below and parallel to the inguinal ligament. The point of origin of the vascular pedicle is determined by palpation of the femoral artery within the femoral triangle, the depression visualized immediately inferior to the fold of the groin. This triangle is formed by the inguinal ligament superiorly, the medial border of the sartorius laterally, and the lateral border of the adductor longus medially. The projected course of the sartorius is marked to define the lateral boundary of the femoral triangle.

The standard flap is incised completely around the flap design. For the island flap, a transverse incision extending from the medial edge of the adductor longus to the lateral edge of the sartorius muscle (overlying the femoral triangle) allows identification of the vascular pedicle. The pedicle is dissected to the medial edge of the sartorius muscle where the superficial and deep branches penetrate the deep fascia. After identification of the vascular pedicle, the skin incision is outlined over the lateral groin extending beyond the anterior superior iliac spine. An incision is made around the planned skin island extending through the deep fascia.

Patient Positioning

The patient is placed in the supine position with a beanbag or folded towel under the posterior iliac spine on the side of the planned flap.
GUIDE TO FLAP DISSECTION

Standard Flap

A Doppler probe helps to locate the pedicle over the medial edge of the sartorius and trace its course laterally to the anterior superior iliac spine. The venae comitantes are either located deep to the femoral artery entering the femoral vein or entering the saphenofemoral vein junction. The superficial vein, the primary draining vein of the flap, is located superficial to the superficial circumflex iliac artery and drains into the saphenous vein at the level of the saphenous bulb located immediately distal to the fossa ovalis. The deep branch courses into the medial aspect of the belly of the sartorius before perforating the anterior surface of the muscle to enter the deep aspect of the overlying fat and skin. Dissection of this vessel creates a perforator groin flap with a potentially longer pedicle.

The flap is elevated in a distal to proximal direction. The skin is incised around the lateral, superior, and inferior margins. Elevation is begun in a plane directly superficial to the fascia lata. The flap is elevated from the anterior superior iliac spine and the external oblique fascia and inguinal ligament. When the sartorius muscle is visualized, the flap is elevated deep to the investing fascia immediately superficial to the muscle belly. The medial edge of the sartorius muscle denotes the proximal limit of standard flap elevation.

Fig. 10E-4  A, Relationship of the pedicle to fascia and sartorius. B, Relationship of flap pedicle to groin muscle and fascial layers: standard flap with base intact. C, Exposure for island flap or free flap and isolation of the pedicle. The medial incision is made first to locate and confirm the SCIA pedicle.
Island Flap
After identification of the vascular pedicle within the femoral triangle through a transverse incision, the location of the distal skin island is outlined and incised. The distal skin island is now elevated as described for standard flap elevation. At the medial edge of the sartorius muscle, the flap elevation is completed with release of the deep fascia until the skin island dissection communicates with the proximal dissection of the isolated vascular pedicle.

Fig. 10E-5
Microvascular Island Flap

The groin flap can easily be used as a free tissue transfer based on the vascular dissections noted above. During flap elevation over the sartorius muscle, the dissection is performed beneath the deep fascia to avoid injury to the vascular pedicle as it penetrates the deep fascia and enters the subcutaneous tissue lateral to this muscle. If pedicle lengthening is required, the deep branch can be dissected through the superficial aspect of sartorius.

Fig. 10E-6  A, Vascular anatomy of the groin flap and perforator variant. B, Vascular basis of the groin flap.
Fig. 10E-6  C, Elevation of island or free flap based on the perforators of the superficial branch of the SCIA.
Delay Flap
It is not uncommon that a standard groin flap would provide too little length for applications on the hand, arm, thigh, or lower abdomen. However, the groin flap can be progressively lengthened using a flap delay technique.

To delay a groin flap, the entire standard flap is elevated as described, except the distal incision is not made. Instead, the upper and lower incisions are lengthened an additional distance posteriorly, equal to the width of the flap (Fig. 10E-7, A). It is essential that the entire flap be undermined up to the medial border of the sartorius muscle, so the only blood...
supply from a proximal direction is this vessel. After 10 to 14 days, the flap may be extended further posteriorly, again by the same amount as the diameter of the flap. One way to think about this amount of lengthening is that a 1:1 flap can be safely transferred anywhere in the body, and in this instance a 1:1 flap is simply being added to an already viable flap (Fig. 10E-7, B). Again, the extension is completely undermined.

The delay can be repeated as needed. Each time, during the delay periods, flow is coming only from proximal and distal, and the flow within the flap is becoming more axial. Some surgeons place a silicone sheet under the delayed segment to prevent vascular ingrowth that can spoil the delay effect. This is not necessary for a single delay but can be considered if more than one delay is planned.

Once the desired length has been achieved, after 1 week the distal end is divided. Now the flap only receives arterial inflow and venous outflow from the proximal flap. It is prudent to wait an additional week for transfer and use, although some would use the flap immediately. If the surgeon discovers a vessel that was not divided during the delay, but should have been, that vessel is now divided and elevation of the flap aborted, because the delay procedure has trained the tissue, in part, on that vessel too. The delay can be completed after 1 additional week.

Again, this delay technique, which is common for the groin flap, can be used anywhere on the body when more than the standard flap is required and there is time to perform the delay correctly.

**Fig. 10E-7**  
A, For a delay groin flap, standard flap elevation is performed—without the distal incision. Upper and lower incisions are lengthened posteriorly by the width of the flap. The flap is completely undermined (green shaded area). B, Ten to 14 days later, the flap can be extended; the delay can be repeated as needed. (1, Length of standard flap; 2, initial delay; 3, second delay at 10 to 14 days.)
ARC OF ROTATION

Standard Flap

The point of rotation occurs over the femoral vessels beneath the inguinal ligament. The flap will reach the abdominal wall and perineum. It is also useful for coverage of distant upper extremity defects.

FLAP TRANSFER

The flap is transferred to its recipient site as either a pedicled transposition flap, a tubed pedicled flap requiring subsequent division, or a single-stage free flap. The tubed pedicled flap should be divided at 3 weeks or partially divided at 10 days, followed by complete separation at 2 to 3 weeks.

The standard flap is transposed directly into the adjacent defect without use of a tunnel. A backcut along the inferior transverse incision over the inferior aspect of the femoral triangle will increase the flap’s arc of rotation.

The island flap may require the use of a tunnel, since a skin flap is completely incised from the flap base. The overlying skin tunnel will prevent exposure of the proximally located vascular pedicle if the flap is transposed into an adjacent defect.

FLAP INSET

Excess subcutaneous fat may be removed from the deep surface of the flap lateral to the lateral edge of the sartorius muscle. The skin of the flap is sutured into the skin edge of the defect. The proximal portion of the flap is tubed if the flap is inset into an upper extremity defect.
DONOR SITE CLOSURE
To avoid a contour deformity, direct donor site closure is performed whenever possible. A tubed flap is used for upper extremity coverage, and the distal donor site is closed directly. The midportion of the donor site beneath the tubed area of the flap will require either skin grafts or temporary wound dressings. At the time of flap division and inset, the unused portion of the tubed flap is returned and inset into the central donor site to complete direct donor site closure. With the use of an extended wide standard flap, donor site closure generally requires skin grafts.

CLINICAL APPLICATIONS
This 24-year-old woman was involved in a rollover motor vehicle accident and sustained this avulsion-type injury, leaving an exposed right elbow joint that required coverage. She also incurred other traumatic injuries. Because of her age and the premium placed on locating donor site scars in a hidden area, a groin flap was chosen to reconstruct the defect.

Fig. 10E-9  A, Defect 1 week after the accident, when the patient’s condition had been stabilized. B, Planned groin flap; an SCIA pedicle is diagrammed. The extension of the flap beyond the ASIS was thought to be the largest flap possible without employing a surgical delay procedure. C, The flap was elevated, tubed, and attached to the defect. To avoid tension at the inset, the distal end of the tube was left open and grafted. D, Division and inset at 2 weeks postoperatively. The initial bulk was necessary to allow healing with good-quality tissue coverage. The patient underwent revisions at 4 months and 8 months after this division. Note how the tubed flap is partially returned to the recipient site, in this case reconstructing an open wound that developed as a partial dehiscence of the initial donor site closure. The amount of pedicle returned should be guided by the desired appearance of the donor site scar. (Case supplied by MRZ.)
This 35-year-old factory worker caught her hand in machinery at work and presented with a dorsal skin avulsion of the hand and extensor tendon, a collateral ligament injury to the ring finger, and fractures of her middle, ring, and small fingers. Forty-eight hours after the initial washout and debridement of nonviable tissues, the patient was returned to the operating room for fracture and tendon repair, followed by soft tissue coverage with a groin flap.

Fig. 10E-10  A, The hand wound at 48 hours, ready for tendon repair and soft tissue coverage. B, The groin flap raised and tubed, ready for inset at the recipient site. C, At inset, with primary closure of the donor site. D, Division and inset at 2 weeks. E, At the 2-month follow-up visit. Care was taken not to be too aggressive at the division and inset and to prepare the patient for revisions at 4 months. F, After one revision, 4 months after the initial groin flap procedure. A wedge of central skin and fat was resected and the flap thinned under direct vision. The patient is shown 3 months after the debulking and recontouring procedure. G, Lateral view. (Case supplied by MRZ.)
This 32-year-old soldier sustained severe burns to the majority of his body from the explosion of an improvised explosive device (IED) in the Iraq conflict.

Fig. 10E-11  A and B, The patient developed a severe contracture of his first webspace. His donor sites were limited; however, while his groin had been burned, it had healed without skin grafting. C and D, A pedicled groin flap was chosen for coverage, and after release of his contracture, the flap was placed in this first webspace and palm. The flap had healed well by 3 weeks and was divided and inset. This provided an excellent release and good hand function. E-G, The patient's hand function is seen 3 months after release of the flap. (Case courtesy William C. Pederson, MD.)
This 43-year-old firefighter lost his left thumb from a thermal injury. A great toe transfer was planned, but more tissue is always required at the hand.

Fig. 10E-12  A, As a first stage, a pedicled groin flap was placed and tubed to position the toe transfer in this tubed flap. B, The flap was divided 3½ weeks later; the flap is shown 4 weeks after division. C, The great toe transfer was performed; the previously placed groin flap allowed transfer of the toe without the need for an undue amount of tissue to be transferred from the foot. D, The patient regained excellent function of his thumb, and he was able to return to duty as a firefighter. (Case courtesy William C. Pederson, MD.)
This 38-year-old man developed necrosis of his hands from pneumococcal sepsis.

Fig. 10E-13  A, The patient's right hand is seen preoperatively. B, To salvage the proximal phalanges, the hand was debrided and placed in a pedicled groin flap. C, The flap was delayed and divided at 4 weeks, with the fingers and thumb syndactylized. D and E, The patient eventually regained reasonable metacarpophalangeal joint motion and thumb opposition after division and insetting of the flap. (Case courtesy William C. Pederson, MD.)
Pearls and Pitfalls

• The groin flap was one of the first free flaps used because of its desirable donor site scar. Today, however, it is infrequently used as a free flap because of its anatomic variability and small vessel length and diameter.

• If microvascular transplantation is selected, the vascular pedicle is identified proximally before skin island elevation. If the pedicle is absent or the superficial circumflex iliac artery is diminutive or double and has an inadequate external lumen diameter, the transverse incision over the femoral triangle is closed and the opposite groin explored. If the vascular pedicle is inadequate after incision into the region of the femoral triangle, it is also possible to identify the superficial inferior epigastric vascular pedicle and incorporate its vascular territory in the inferior ipsilateral abdominal wall as an alternate flap design for microvascular composite tissue transplantation.

• During flap elevation over the sartorius muscle, the dissection is performed beneath the deep fascia to avoid injury to the vascular pedicle as it penetrates the deep fascia and enters the subcutaneous tissue lateral to this muscle.

• If pedicle lengthening is required, the deep branch can be dissected through the superficial aspect of the sartorius muscle.

• If greater flap length is required, a delay technique should be considered.

• The distal end of the flap can be split into short, fingerlike leaflets to reach several adjacent small defects.

EXPERT COMMENTARY
William C. Pederson

Indications
The primary indication for this flap is as a pedicled flap for coverage of hand and forearm wounds. Probably the best indication is the first stage in thumb reconstruction with toe transfer (to provide needed extra soft tissue). This flap is excellent for dorsal defects and works well in thinner patients for first webspace coverage and/or release. It may also be used for distal half forearm coverage. The flap is rarely indicated as a free flap, since many other cutaneous flaps exist; however, it does offer perhaps one of the best donor sites for a cutaneous free flap.

Advantages and Limitations
The primary advantage of the groin flap is that it provides excellent soft tissue coverage of hand wounds without the need for microsurgery. This comes into play particularly when one is planning a great toe transfer for thumb reconstruction. The use of a pedicled groin flap as a first stage to provide adequate soft tissue can make the toe transfer simpler by avoiding the need for a microvascular anastomosis, which might make vascular access for the toe transfer more difficult.
The pedicled groin flap has limited applicability in patients who are very obese because of the potential thickness of the flap. Also, its dimensions are limited somewhat by the need to close the donor site primarily. I think that any defect that requires a pedicled groin flap that could not be closed primarily (usually about 12 to 14 cm wide) should be covered using another technique. Although it is certainly possible to cover the donor site with a split-thickness skin graft, I think this is suboptimal and prefer to choose a different flap. Another disadvantage is that the hand must be placed in a dependent position while it is attached to the groin. This delays physical therapy and can lead to more swelling.

Anatomic Considerations
I always listen with a pencil Doppler to attempt to identify the superficial circumflex iliac artery, which one can usually hear along its course to about the level of the ASIS. I also make a line for the center of the flap two fingerbreadths below the inguinal ligament and make the flap width equidistant from each side of this line.

Personal Experience and Insights
The pedicled groin flap remains one of the best flaps for hand coverage of moderate to extensive wounds. It is an excellent choice for coverage of the first webspace after release (in thin patients) and provides excellent coverage before secondary microsurgical procedures, such as toe transfers. Although microsurgical tissue transfer has perhaps delegated the pedicled groin flap to secondary status for some, it is often the primary choice of coverage in my hands.

Recommendations

Planning
The flap design is centered over the signal from the superficial circumflex iliac artery. Quite wide flaps (10 to 12 cm) can be elevated in most patients, but the hip will have to be extended and the knees flexed to facilitate closure. The flap is made longer than necessary to allow tubing of the proximal part, which will permit some motion of the wrist, elbow, and shoulder.

Technique
The superficial circumflex iliac artery is identified with a pencil Doppler in its usual position 2 cm below the inguinal ligament. The flap is elevated from lateral to medial, defatting the lateral portion of the flap as it is raised (otherwise, this would have to be done later anyway). When the lateral border of the sartorius muscle is reached, the fascia is incised and the flap elevated in a subfacial layer to avoid damage to the superficial circumflex iliac artery. The donor site is closed before the flap is inset on the hand, and the proximal portion of the flap is tubed if at all possible. This will require extension (forward flexion) of the hip and flexion of the knee. The operating table should be flexed maximally at the patient’s hips, with several pillows placed under the patient’s knees after the flap is elevated and before closure is attempted to remove the tension.

Postoperative Care
I place a large suture between the wrist and torso until the next morning when the patient is fully awake to help prevent dehiscence of the flap from the hand. (I have never seen a patient pull the flap off once he or she is fully awake, but this can occur while the patient is thrashing around in the recovery room.) Ambulation begins 1 or 2 days postoperatively, and usually over the first 3 or 4 days the patient will be able to stand straight.
If the flap is well healed in on the hand at 3 weeks, the flap can safely be divided. The timing of flap division is predicated on the adequacy of the new blood supply from the soft tissues of the hand. If the wounds have dehisced a bit or do not appear to have healed in, I usually wait another week.

Another option is to perform a “delay” procedure on the flap. At 3 weeks, the skin and dermis of the flap can be incised or a small incision made in the flap and the deep tissues divided (which should divide the superficial circumflex iliac vessels). This will allow safe division of the flap a week later.

**Complications: Avoidance and Treatment**

Dehiscence of the flap can be avoided by the maneuvers just described. If within the first 2 or 3 postoperative days a line of ischemia is noted in the distal flap, the patient is returned to the operating room; the nonviable portion of the flap should be debrided and the flap reinsert. Tubing of the proximal flap will usually give enough extra flap to allow this.

If an infection develops at the donor site, do not open it and leave it open! This will lead to a wound that is extremely difficult to manage and will usually require a long course of dressing changes and eventually a skin graft. The infected donor site should be managed closed if at all possible, with repeated irrigation and drains. The infection will eventually resolve and heal, with far fewer problems than if the wound is opened and left open.

**Take-Away Messages**

The pedicled groin flap remains one of the workhorses for soft tissue coverage of the hand. If done carefully and extra length is taken, the flap can be tubed a bit, which will allow some motion of the wrist, elbow, and shoulder. Although an excellent choice for soft tissue coverage, the flap does not import a blood supply, and thus its indications are limited in dysvascular limbs and severely contaminated wounds.

**Bibliography With Key Annotations**

**Anatomic Studies**


*These early pioneers of microvascular surgery described their anatomic cadaver dissections and clinical experience with the free groin flap. They clearly detailed the vascular basis of this flap and its variability. In their experience with 16 flap elevations in cadavers and 70 clinical flaps, they commented that there were no vessels large enough to supply the flap in four cases. In all the other patients, the flap was supplied to some extent by the superficial inferior epigastric artery and the superficial circumflex iliac artery, and venous drainage was through the superficial axial vein running in the flap. They noted that the superficial inferior epigastric artery and the superficial circumflex iliac artery arose from a common trunk in 25 instances. They also pointed out that survival of the flap does not require reanastomosis of both the superficial inferior epigastric artery and superficial circumflex iliac artery. Either of these vessels is sufficient to carry the entire flap.*


*The authors’ anatomic studies included cadaver dissections and radiographic studies of the superficial circumflex iliac artery. These vessels were cannulated and injected with contrast material during the course of radical lymph node dissection. In their 14 anatomic cadaver dissections, the authors noted that in 13 cases the vessel was a direct branch of the femoral artery and in one case a branch of the superficial inferior epigastric artery. The course of the vessel essentially paralleling the inguinal ligament was demonstrated.*

The vascular anatomy of potential flaps suitable for microvascular transplantation was studied in cadavers. Specific areas evaluated included the iliofemoral, deltopectoral, axillary, chest, and popliteal regions. The authors recommended the regional iliofemoral flap based on the superficial circumflex iliac and superficial inferior epigastric systems as the best donor site for most regions. In their clinical series of five patients, the largest flap from this area measured 15 by 24 cm. The deltopectoral flap designed on the second or third perforators was recommended as the best alternate donor site region, since the flap is thinner and provides a better color match for head and neck reconstruction.

Clinical Series

The authors reported their experience in 16 patients in whom vulval reconstruction with bilateral island groin flaps was performed. They advocated this as a useful flap not only for reconstruction of the vulva but also for access for groin dissection in these patients with vulvar carcinoma.


The authors reviewed their experience with 73 free groin flaps performed between 1985 and 1990. During that 5-year interval the authors performed a total of 1096 free flap reconstructions. The groin flaps therefore represented only 7% of their experience during that period. The complication rate was 8%. They had three complete failures and three partial failures. They stated that part of the problem with the flap is the small diameter of the superficial circumflex iliac artery, and suggested two ways of overcoming the small pedicle size: (1) harvest of a cuff of femoral artery with the superficial circumflex iliac artery to facilitate microvascular anastomosis of the artery and (2) use of a longitudinal split of the Y-shaped bifurcation of the superficial circumflex iliac artery if available. In the authors’ experience, this Y-shaped bifurcation is quite common. In their clinical series the authors demonstrated the versatility of this thin cutaneous flap for extremity coverage.


The authors described a method of fixing the wrist to the iliac crest with a Hoffman external fixation device to immobilize the thumb during a staged thumb reconstruction using a groin flap.


The authors presented two cases in which the soft tissues of the face were augmented with a deepithelialized free groin flap. In their first patient, a 9-year-old boy, the authors performed a flap revision 3 years later because of sagging.


The authors described bilateral simultaneous groin flaps for coverage of the dorsum and volar aspect of the hand. The two flaps were elevated simultaneously and one placed over the dorsum and one on the volar aspect. They demonstrated successful reconstruction in two patients with mutilating hand injuries involving both the dorsal and palmar surface of the hand.


The authors reported their experience with 33 consecutive cases of free groin flaps in children over a period of 9 years (1992 to 2001). Flaps were performed to provide soft tissue coverage during reconstruction of congenital defects and tumor resection and following trauma. Twenty-six cases (79%) involved the upper limb, six cases (18%) involved the lower limb, and one case involved the head. The complication rate included only two failures (6%), three (9%) minor donor-site complications (super-
ficial wound infection, hypertrophic scarring, and dog-ears), and nine flaps requiring debulking. The reexploration rate was 24%, with seven of the eight flaps undergoing reexploration surviving. They concluded that the groin flap is reliable and can be used safely in children, with minimal morbidity.


The authors reviewed the decline in popularity of the groin flap because of the availability of more versatile free flaps. They highlighted some of the traditional groin flap’s inherent disadvantages, including a short arterial pedicle, variable arterial anatomy, the small caliber of the included blood vessels, its bulk, and numbness at the donor site. They addressed several of these criticisms by developing alternative methods of dissection, including the use of the SCIA axis as a perforator groin flap with extended pedicle. Clinical experience was presented, with the modified flap in 12 patients (age range 15 to 67 years) in surgical procedures involving nine recipient sites in the upper limbs, two in the foot, and one in the mouth. They concluded that the SCIA flap overcomes most of the disadvantages of the free groin flap and demonstrated its advantages, including (1) a concealed donor-site scar, (2) primary closure of the donor site, (3) procurement of a large cutaneous flap (25 by 8 cm to 6 by 4 cm), (4) non-hair-bearing skin, (5) longer arterial pedicle (3 to 13 cm), (6) typically requiring no vessel grafting, (7) reduction in bulk, (8) a decreased area of numbness at the donor site, and (9) less time required for flap dissection (0.5 to 1.5 hours). The SCIA perforator flap was presented as an evolution of the conventional free groin flap.


This was the original description of the groin flap. The authors stated their belief that the success and safety of Bakamjian’s deltopectoral flap was based on a virtually closed arteriovenous system deriving from and draining back into the perforating branches of the internal mammary system. Therefore they attempted to identify such a vascular system in other areas. In reviewing previous anatomic descriptions and drawings, the authors concluded that the superficial circumflex iliac arteriovenous system may well support a flap. The area of skin supplied by the system was called the groin flap by the authors. In this article they described the anatomic basis and clinical demonstration of the groin flap for coverage of the hand and staged transfer to the scalp. This landmark article was the impetus for others to search for “similar” axial flap donor sites.


The author described a multistaged (seven-stage) reconstruction of the penis in four patients. A groin flap and an opposite upper thigh flap were used to reconstruct a penis with a lined urethra and a separate lined pocket into which a penile prosthesis may be placed.


This was one of the original descriptions of a free microvascular flap transfer. The groin flap was used for coverage of a defect of the lower third of the leg and ankle in a young man with a close-range shotgun wound. The anatomic basis of the flap based on 43 cadaver dissections was presented; the arterial anatomy was confirmed. The feasibility of microvascular transplantation of axial flaps was successfully demonstrated in this case, despite numerous complications and a redo of the vascular anastomosis because of thrombosis. The problems encountered in such microvascular transplantations and the hurdles that had to be overcome before microvascular tissue transplantation became commonplace were vividly portrayed in this early report.


The authors presented their experience with the use of an island groin flap in nine patients. The pedicle island flap was used for reconstruction of the upper thigh, lower abdomen, and perineum. The arc of rotation of the flap and its successful use for coverage of defects in these areas was well demonstrated.

In this interesting article the authors presented two patients in whom the groin flap was used to cover two separate anatomic areas. In the first patient the hand and neck were covered with a groin flap, with the hand acting as a carrier for the groin flap to the neck. In a second case the distal portion of the groin flap was used for coverage of a hand defect. When the flap was divided 3 weeks later, the proximal portions of the flap were transferred as a free flap for coverage of a right foot defect. This article illustrated the versatility of this flap and its practical applications based on a knowledge of the vascular anatomy and the ability to transfer tissues by microvascular transplantation.


The author reviewed his experience with 33 free groin flaps for coverage of complex lower extremity defects. Of the 33 flaps, there were seven failures, including one compound osteocutaneous flap, which represents a failure rate of 21%. Six of the 33 flaps were compound osteocutaneous flaps.


The author described several important steps in the elevation and tubing of the groin flap for hand coverage. These include the preservation of the lateral femoral cutaneous nerve of the thigh and a modification of flap design in which the upper incision is longer than the lower incision, and the flap is tubed diagonally rather than straight across. This allows easier rotation of the tube and facilitates donor site closure.


The authors reported their experience with nine patients who underwent reconstruction of head and neck defects with free flaps. The dorsalis pedis flap was used in three patients, the groin flap in four patients, and the latissimus dorsi flap in two patients. The authors preferred to elevate this flap from lateral to medial and presented successful reconstructions with the flap.


The authors described a series of patients in whom reconstruction of the vagina, penis, and groin was performed with groin flaps and superficial inferior epigastric artery flaps. In a number of patients a combination of flaps was used. A composite iliac crest bone and groin flap was used in 11 patients for penile reconstruction.


The authors reported their experience with 11 cutaneous and musculocutaneous free flaps for facial contour reconstruction: Romberg’s disease (4), lateral facial dysplasia (1), following tumor resection (2), and lipodystrophy (4). In nine of their patients deepithelialized groin flaps were used. All flaps were successful, and in every patient suitable vessels were found for microvascular transplantation. Follow-up ranging from 6 months to 3½ years showed that the flaps maintained their bulk and position.


The authors reported their experience between 1971 and 1972 in 27 patients who underwent groin flap reconstruction of hand injuries. All patients had severe crush-avulsion injuries with soft tissue loss. In all patients the flap was transferred as a staged procedure. They reported an 18% incidence of flap necrosis due to ischemia. In all cases flap necrosis occurred after the final division of the pedicle and was more common following immediate insetting of the flap than after delaying the inset. The authors noted that flap necrosis did not develop if the pedicle was divided in two stages.
Flap Modifications


The authors elevated the groin flap together with the underlying iliac crest bone for reconstruction of complex defects of the wrist and forearm in two patients. Missing bone, skin, and subcutaneous tissues were replaced with a pedicle groin flap in two patients. This staged procedure was successful in reconstruction of a wrist and forearm defect. Bone scans at 8 weeks confirmed the viability of the transferred iliac crest bone.


To ensure the standard groin flap is uniformly thin and has a long vascular pedicle, the author places the skin island farther laterally so that the medial border of the skin island is placed along the lateral border of the femoral triangle. The author presented his experience with 18 free iliac flaps. Twelve of 18 flaps were used for immediate reconstruction of intraoral defects. Thirteen of the 18 flaps were successful, and five were failures. One failure was attributed to errors in flap elevation, one failure to tortuosity of the arterial anastomotic site, another to intraoperative vasospasm, and two to compression of the vascular pedicle.


In an unusual case report, the authors split a groin flap and transferred one part as a free flap for reconstruction of an opposite wrist and used the remainder as a pedicle flap for coverage of an ipsilateral wrist defect. The branching pattern of the superficial circumflex iliac artery makes this modification possible.


The authors described the inclusion of the underlying iliac crest with the groin flap for primary thumb reconstruction, thus transferring the soft tissue and bone as a composite flap in this staged reconstruction.


A combined latissimus dorsi–groin flap was designed with the flap located on the lateral flank extending between the axilla and groin. The flap was used to cover an extensive defect extending between the medial upper arm and forearm. The groin pedicle was divided at 14 days and flap inset completed 1 week later. Because a vein graft had been used earlier to revascularize the upper extremity, suitable receptor vessels for microvascular flap transplantation were not available. This technique provides a long flap with a width of 12 cm for coverage of a large upper extremity defect with the upper extremity maintained in an acceptable position following flap inset.


The authors presented a new technique for raising a microdissected thin groin flap. The flap is uniformly thin with a long vascular pedicle prepared by microdissection of the deep branch of the superficial circumflex femoral system (SCIS). Thirty cases were reconstructed using microdissected thin groin flaps. One flap was lost because of a venous thrombosis. A small distal area of three large flaps became necrotic. The perforators from the deep branches were absent in five cases, and three of these flaps were successfully elevated based on the superficial branch using the new method. The clinically safe dimensions of the flap ranged from 5 by 2 cm to 25 by 12 cm.


The groin flap is usually used as a syndactylized sheet to cover multiple defects of the fingers. The authors presented a novel technique for splitting the flap into daughter flaps based on the SCIA vessels.
This was one of the early reports of microvascular transplantation of the groin flap with iliac crest bone for reconstruction of complex leg defects. Later studies by Taylor showed that the deep circumflex iliac artery provided a better blood supply to the iliac crest.

The authors reported their experience in reconstruction of complex defects of the lower leg involving the Achilles tendon and calcaneus. Eight patients were included in this series. In patients with skin, soft tissue, and Achilles tendon loss, a free groin flap that included sheets of external oblique aponeurosis was transferred, and the aponeurosis was rolled to form a tendonlike structure to replace the Achilles tendon. Coverage was provided by the overlying groin flap. In a separate group of patients the groin flap with iliac crest bone was transferred. The bone was used for reconstruction of the calcaneus. All reconstructions were successful. Two patients had some partial skin loss. The authors demonstrated the feasibility of reconstruction of the Achilles tendon with a piece of vascularized external oblique aponeurosis carried with the groin flap.
ANATOMIC LANDMARKS

**Landmarks**  The flap incorporates the skin and fascia extending from the abdominal midaxillary line laterally.

**Size**  $25 \times 7$ cm.

**Composition**  Fasciocutaneous.

**Flap Type**  Type C.

**Dominant Pedicle**  Myocutaneous perforators via the rectus abdominis muscle.

**Minor Pedicle**  Two or three subcostal arteries.

**Nerve Supply**  Anterior division of the lateral cutaneous branches of the sixth through tenth intercostal nerves.
Section 10F

ABDOMEN

Thoracoepigastric (Transverse Abdominal) Flap

CLINICAL APPLICATIONS

Regional Use
- Anterior thorax
- Breast
- Abdomen
ANATOMY OF THE THORACOEPIGASTRIC (TRANSVERSE ABDOMINAL) FLAP

Fig. 10F-1

**Dominant pedicle:** Myocutaneous perforating arteries from superior epigastric artery
ANATOMY

Landmarks  Flap incorporates the skin and fascia extending from the abdominal midaxillary line laterally.
Composition  Fasciocutaneous.
Size  25 × 7 cm.

Arterial Anatomy (Type C)

Dominant Pedicle  Myocutaneous perforators via the rectus abdominis muscle
REGIONAL SOURCE  Superior epigastric artery.
LENGTH  2 cm.
DIAMETER  0.5 mm.
LOCATION  Myocutaneous perforators extending from the rectus abdominis muscle through the anterior rectus sheath into the fat of the flap.

Minor Pedicle  Two or three subcostal arteries
REGIONAL SOURCE  Thoracic aorta.
LENGTH  2 cm.
DIAMETER  1 to 1.5 mm.
LOCATION  These vessels enter the midportion of the deep aspect of the rectus abdominis in conjunction with the intercostal motor nerves. They anastomose with the superior epigastric artery within the muscle contributing to the myocutaneous perforators entering the flap base. The contribution from T8 is the largest segmental branch.

Venous Anatomy

The venous anatomy is via perforators that accompany the superior epigastric vein. In the subcostal vessels, venous drainage is via the hemizygos and azygos veins.

Nerve Supply

Anterior division of the lateral cutaneous branches of the sixth through tenth intercostal nerves.
Vascular Anatomy of the Thoracoepigastric (Transverse Abdominal) Flap

Deep surface of flap

Flap base at lateral edge of rectus sheath

Deep surface of flap

Radiographic view

Fig. 10F-2

Dominant pedicle: Myocutaneous perforating arteries (D)
**FLAP HARVEST**

**Design and Markings**
The skin flap is oriented either transversely or slightly obliquely across the lateral trunk. The base of the flap extends between the xiphoid process and a point 7 cm below this. Two parallel lines drawn from these two points extending laterally or obliquely will form the upper and lower limits of the flap boundaries. The two parallel lines are then joined as either an elliptical or a rectangular termination.

*Fig. 10F-3*

**Patient Positioning**
The patient is placed in a supine position.
GUIDE TO FLAP DISSECTION

The upper and lower incisions are incised, and the upper dissection is carried down over the serratus anterior muscle; the inferior incision is extended down to the external oblique muscle. The tip of the flap is then raised immediately superficial to the serratus and external oblique fascial layers, moving progressively from lateral to medial. Dissection extends to the linea semilunaris medially. Further medial dissection can be performed until the perforators are seen, but this dissection can be dangerous in that it may cause pedicle damage, rendering the flap ischemic.

An inferior backcut toward the midline can expedite flap rotation superiorly. The tip of this flap beyond the anterior axillary line is not as reliable as the more proximal components and flap viability can be enhanced using the vascular delay procedure 3 to 7 days before flap elevation.
FLAP VARIANT
• Extended VRAM (eVRAM) flap

ARC OF ROTATION
The flap can be rotated from 45 to 90 degrees up onto the chest or down onto the abdomen.

FLAP TRANSFER
The flap is always used as a pedicled procedure, and during transposition, care should be taken to prevent undue tension from the pivot point or kinking of the small and somewhat fragile perforators.

FLAP INSET
The flap is sutured to the recipient bed using absorbable sutures in a two-layer closure incorporating Scarpa’s fascia as the deep layer.
**DONOR SITE CLOSURE**

If the donor site is too tight, it should be closed with a skin graft. Usually, however, it is feasible to close it directly, but it is imperative that the deep layer include a competent Scarpa's fascia repair.

**CLINICAL APPLICATION**

This 72-year-old man had a sarcoma of his left hip and received neoadjuvant chemotherapy followed by radiation therapy. Surgical resection and reconstruction were indicated.

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Fig. 10F-6  
A, This lateral view of the patient’s left hip shows the soft tissue defect that resulted from sarcoma resection.  
B, An elliptical vertical rectus abdominis myocutaneous (VRAM) flap was designed over the rectus abdominis muscle, with four perforator zones (dots) identified. The thoracoepigastric extension (eVRAM) was marked, extending from the umbilicus toward the costal margin at the anterior axillary line.  
C, The eVRAM flap was elevated.  
D, It was transposed through a tunnel into the left hip soft tissue defect.  
E, The flap was tailored and inset into the defect, covering all vital structures. The rest of the wound was skin grafted. (Case courtesy Justin M. Sacks, MD.)
Pearls and Pitfalls

- Care should be taken not to outrun the flap’s blood supply by extending dissection beyond the midaxillary line.
- Vascular delay can augment tip vascularity.
- Judicious backcutting involving the skin only can facilitate flap rotation to some degree. When performing this maneuver, care should be taken not to damage the inferior perforator supply.

EXPERT COMMENTARY

Justin M. Sacks

Indications

The thoracoepigastric flap provides an axial-based fasciocutaneous flap for defects of the abdomen, anterior thorax, breast, and the ipsilateral upper extremity. This flap is appropriate when there is a shortage of skin after mastectomy or for smaller chest wall defects. When the thoracoepigastric flap is incorporated into an inferiorly based pedicled VRAM flap, it can be considered an extended VRAM (eVRAM). When the flap is used in this fashion, defects that can be reconstructed include the perineum, pelvis, groin, and hip regions.

Advantages and Limitations

This is the procedure of choice for patients requiring soft tissue for the chest wall who are not appropriate candidates for an abdomen-based flap in the form of a free tissue transfer, such as a free TRAM flap, muscle-sparing TRAM, or a deep inferior epigastric artery (DIEA) flap, or if a patient is unable to have the latissimus dorsi muscle transferred, with or without a skin paddle. If no free tissue transfer is appropriate, then the thoracoepigastric flap can potentially provide appropriate soft tissue coverage. The advantages of this flap are its technical ease, local donor area, and primary donor site closure. The scar can be covered on the brassiere line, and the tissue transposed is robust.

Continued
In the setting of breast reconstruction, if the inframammary fold is violated, then there is a chance the perforators to the thoracoepigastric flap will have been violated. The flap will not correct an infraclavicular hollow or be able to re-create an anterior axially fold.

**Anatomic Considerations**
The transverse thoracoepigastric flap has an axial blood supply based on lateral perforators from the superior epigastric artery and vein. The flap is considered random when it is extended past the anterior axillary line and placed between or up to the posterior axillary line.

**Personal Experience and Insights**
An eVRAM flap can incorporate a portion of the thoracoepigastric flap. The terminal portion of the eVRAM will act as the equivalent of the thoracoepigastric flap. Thus the indications for the thoracoepigastric flap are broadened, and this flap can be considered for reconstruction of other areas, such as the pelvis, perineum, and hip regions.

**Recommendations**
When raising the thoracoepigastric flap, it is important to base and center the flap over the perforating vessels from the superior epigastric system. Transcutaneous Doppler imaging, CT angiography, and near-infrared laser angiography using indocyanine green can help optimize the location of the base of the thoracoepigastric flap. The flap, by definition, is always used as a pedicled procedure. However, when it is raised with the VRAM, it can be considered an eVRAM. In this case, the thoracoepigastric flap becomes an extension of the VRAM, and the flap is not as limited in its rotation. This variant of the flap relies on the anastomosis of the intercostal system and the superior epigastric system. When the flap is solely based on the perforators of the superior epigastric flap, care must be taken to prevent undue tension at the pivot point. The flap is sutured to the recipient bed using absorbable sutures in a two-layer closure incorporating Scarpa’s fascia as the deep layer. Closed suction drains are recommended at all aspects of the flap donor site and inset. If the donor site is closed too tightly, necrosis and dehiscence will ensue. In these situations the donor site needs to be closed with a skin graft.

**References**

**Bibliography With Key Annotations**

**Anatomic Studies**

*The deep epigastric arcade between the superior epigastric artery and deep inferior epigastric artery was described. A transverse abdominal flap was designed based on the perforators through the rectus abdominis muscle. The authors shared their experience using this flap to cover an exposed upper extremity vascular reconstruction in one patient.*
Clinical Series

In this French-language article Bohmert described breast reconstruction in 107 patients using the thoracoepigastric and abdominal advancement flaps. In 76 patients with a vertical or oblique scar, a medially based thoracoepigastric flap was used. In patients who had a transverse scar, an abdominal advancement flap was used. In both groups, a silicone implant was placed under the flap. Satisfactory breast reconstruction was demonstrated.


In this modified transverse abdominal flap the author used the excess abdominal skin and subcutaneous tissues from under the opposite inframammary crease for breast reconstruction. The flap was based on perforators through the rectus abdominis on the same side.


This was the original description of the transverse abdominal or thoracoepigastric flap. The authors described a flap based on the midline and extending to the ipsilateral posterior axillary line. It was based on the upper part of the rectus abdominis. The vascular bases of the flap were perforating vessels from the superior epigastric artery through the rectus abdominis. They presented five patients. In the first three patients the flap was delayed. In the final two patients there was no flap delay. The only complication occurred in a patient who had a nondelayed flap and involved some distal marginal necrosis. The utility of this flap for chest coverage was well demonstrated.

Flap Modifications

The authors performed a modification of a transverse abdominal flap. The flap was based on perforators through the opposite rectus abdominis muscle. They demonstrated clearly that the perforators through the rectus abdominis easily support a transverse flap extending across the midline. They also described the vascular basis for this flap and clinical applications in breast reconstruction and chest coverage.


In this modification of the thoracoepigastric flap the authors extended the flap well beyond the posterior axillary line onto the back. The flap was twice delayed before being used for breast reconstruction with a silicone implant. The article was an early review of breast reconstruction with this flap and a silicone implant. Techniques for nipple-areola reconstruction were also discussed.


Breast reconstruction was performed using the transverse abdominal flap based high up under the opposite breast. This flap was supplied through perforators from the superior epigastric artery. The author also described a laterally based flap for release of burn scar contracture. Perforators from the external oblique provided the vascular basis for this flap.


The authors described their experience with this flap in 114 cases of breast reconstruction. They reported complications of partial flap necrosis in 3.5% of their cases and an infection rate of 2.5%. This was a modification of the standard transverse abdominal flap in that it was based more laterally. In addition to its vascular supply through the rectus abdominis, it was also supplied through the intercostal vessels and perforators through the external oblique.
**ANATOMIC LANDMARKS**

**Landmarks**
This flap extends from the posterior perineum obliquely along the groin to the level of the upper pubis, between the labium majus or scrotum medially and the medial thigh laterally. It abuts the groin crease.

**Size**
15 × 6 cm.

**Composition**
Fasciocutaneous.

**Flap Type**
Type A.

**Dominant Pedicle**
Posterior labial artery.

**Nerve Supply**
_Sensory:_ Pudendal, S2 to S4, and perineal branches of the posterior cutaneous nerve of the thigh, S1 to S3.
Section 10G

ABDOMEN

Pudendal-Thigh (Singapore) Flap

CLINICAL APPLICATIONS

Regional Use
- Perineum
- Scrotum
- Genitourinary reconstruction

Specialized Use
- Vaginal reconstruction
ANATOMY OF THE PUDENDAL-THIGH (SINGAPORE) FLAP

Fig. 10G-1

Dominant pedicle: Posterior labial artery
ANATOMY

Landmarks  
Fasciocutaneous flap based posteriorly in the groin creases; extends from the posterior perineum obliquely along the groin to the level of the upper pubis between the labium majus or scrotum medially and medial thigh laterally. It abuts the groin crease.

Composition  
Fasciocutaneous; based on the posterior labial artery as a direct axial cutaneous vessel.

Size  
15 × 6 cm.

Arterial Anatomy (Type A)

Dominant Pedicle  
*Posterior labial artery*

Regional Source  
Internal pudendal artery.

Length  
10 to 12 cm.

Diameter  
1 to 1.5 mm.

Location  
Internal pudendal artery is the source artery to the perineum through the perineal artery and the inferior rectal artery. The perineal arterial branch courses from posterior to anterior, passing from deep to superficial. At the level of the anus, the vessel gives off a transverse perineal branch, then continues as the posterior labial artery, running from posterior to anterior between the groin crease and the labium or scrotum, superficial to the deep fascia. Distally, the artery anastomoses with terminal branches of the deep external pudendal artery and medial circumflex femoral vessels.

Venous Anatomy

The venous anatomy closely follows the arterial circulation.

Nerve Supply

Sensory  
Pudendal, S2 to S4, and perineal branches of the posterior cutaneous nerve of the thigh, S1 to S3. The anterior portion of the flap loses its sensation during elevation, but the posterior half retains sensation through the posterior labial and perineal branches, as described previously.
Vascular Anatomy of the Pudendal-Thigh (Singapore) Flap

Dominant pedicle: Posterior labial artery (D)

Fig. 10G-2
**FLAP HARVEST**

**Design and Markings**

The skin territory of this flap can be outlined by using Doppler ultrasound to identify the posterior labial vessels. The flap is based posteriorly, and an oblique flap 15 cm long by 5 to 6 cm wide is designed extending from the labium majorum medially to the medial thigh skin laterally, with the flap design abutting the groin crease.

![Bilateral flap skin island design](image)

**Patient Positioning**

The patient is placed either in the lithotomy position or in a supported frog-leg position.
GUIDE TO FLAP DISSECTION

The incision is made around the periphery of the flap, and dissection is carried down to the deep fascia. The deep fascia is incised, and dissection continues from anterior to posterior, deep to the deep fascia in the subfascial plane throughout.

When dissecting over the adductor muscle mass in the medial thigh, the surgeon should elevate the fascia and epimysium over the muscle with the flap. As dissection progresses posteriorly toward the buttock, the subcutaneous tissues become thicker. The position of the pedicle can be checked with Doppler ultrasound during the dissection, and judicious subcutaneous undermining toward the base of the pedicle can be performed to facilitate rotation, taking care not to damage the vessels. If vaginal reconstruction is planned, the flaps can be turned into a true island.

Vaginal reconstruction requires subcutaneous tunneling into the vaginal defect to allow safe and easy transposition of the flap.
**ARC OF ROTATION**

The flap can easily reach the perineum and line the entire vagina, based as it is close to the perineal body. Complete vaginal reconstruction typically requires bilateral flaps. The flap can also reach the proximal medial thigh and the perianal area toward the coccyx.

**FLAP TRANSFER**

Transfer involves transposition into the defect. When used for vaginal reconstruction, this flap is usually used as an island flap tunneled beneath the skin bridge medially to create a suitable introitus, but direct transposition via an incision between donor and recipient sites is also an option.
FLAP INSET
For total vaginal reconstruction, bilateral flaps are used as tunneled island flaps. The apices of the flaps are sutured together, with each flap creating an ipsilateral hemivaginal side wall in its final position. This creates an anterior and a posterior seam within the neovagina. A two-layer closure should be performed, incorporating Scarpa’s fascia in the deep layer as well as a superficial cutaneous closure. The inset into the entrance of the vagina should be spatulated to prevent stenosis. For partial defects, such as those seen in release after introital stenosis or partial vaginectomy, unilateral flaps should be inset without tension with absorbable sutures within the vaginal vault. For cutaneous defects, regular skin closure techniques are appropriate.

DONOR SITE CLOSURE
The donor sites are simply approximated in two layers as oblique linear closures within the groin creases. For simple transplantational flaps that are not tunneled, the closure of the donor site should not compromise the base of the flap where the pedicle lies. Undermining of the thigh skin in the subcutaneous plane can assist in a tension-free closure.
CLINICAL APPLICATIONS

This 22-year-old woman had congenital stenosis of the vaginal vault.

Fig. 10G-9  
A, Appearance of the introitus on clinical examination. It was not possible to examine the introitus with a single finger.  
B, A CT scan showed a significant bony component to the stenosis.  
C, The first stage of reconstruction involved bony resection of the obstructive bone via a suprapubic approach. The vaginal vault was not breached.  
D, Four months later, the soft tissue deficit was addressed with a pudendal thigh (Singapore) flap. The flap was designed as a direct transposition flap, leaving the final donor scar in the groin crease.  
E, The release of the vaginal vault was performed first, confirming length and width requirements. A lateral release provides easy access for the flap and is recommended to avoid issues with the genitourinary and gastrointestinal tracts. Once the flap was transposed, primary closure was obtained. No attempt was made to address dog-ears at this point, to preserve the vascularity to the flap.  
F, The patient is seen 2 months postoperatively. She now has a three-finger introitus and has had successful intercourse. (Case supplied by MRZ.)
This 43-year-old woman was treated with external beam radiation for advanced anal cancer. She subsequently developed introital stenosis, with constriction of her vaginal vault. She had a one-finger introitus and was unable to have intercourse.

**Fig. 10G-10**  
A, Although the radiation therapy had been performed 2 years earlier, the damage to the skin is evident. The damage extended to the tissues of the pudendal thigh flap. Other local options would provide too much bulk to effectively expand a constricted, irradiated vault, so a pudendal thigh flap was attempted in a delayed fashion to maximize vascularity in this irradiated setting. Doppler points are marked with Xs, and the initial flap to elevate is marked. The solid line denotes what would survive primarily; the dotted lines indicate the extension for delay. The area of the pedicle was left intact.  

B, Two weeks later, the initial elevation had done well and the extension was incised and undermined, leaving the distal skin of the flap intact to support the flap during delay. This distal portion of the delay was completed in the office with the patient under local anesthesia 1 week later.  

C, Two weeks after the final delay, the vaginal vault was opened laterally and the flap inset.  

D, Six months postoperatively, the patient had a two-finger introitus, despite dilator therapy. She then underwent the same series of procedures on the contralateral side without complication. She now has a three- to four-finger introitus and is able to have intercourse. (Case supplied by MRZ.)
Pearls and Pitfalls

- The flap is extremely versatile when used for vaginal reconstruction, but it is rendered unavailable if a radical vulvectomy has been performed.
- If the flap is passed through a subcutaneous tunnel into the perineal wound, care must be taken to ensure that there is no compression of the pedicle.
- If an island flap is used, great care should be taken to prevent twisting of the pedicle.
- In males, the flap can be used for scrotal and urethral reconstruction or perineal wounds. The named vessel of the flap in the male is the inferior scrotal artery.
- Care should be taken when elevating the flap and closing the donor site to avoid interruption of the groin lymphatics. Running out of dog-ears superiorly should be done at the subcutaneous level.

EXPERT COMMENTARY
Michael R. Zenn

Indications
The pudendal thigh (Singapore) flap is indicated when sensate reconstruction is required in the perineal area, most commonly for vaginal or labial reconstruction.

Advantages and Limitations
This flap provides thin, pliable, sensate tissues with a favorable arc of rotation for vaginal reconstruction. The donor site is also favorable, because it leaves a donor scar in the thigh crease that is well tolerated. The limitation of the flap is its size: it may not provide enough surface area for the reconstructive need. Cases of total vaginal vault reconstruction have been described using bilateral flaps. In cases in which the patient has undergone previous radiation therapy, the use of the flap is more limited because of scarring and the decreased vascularity of the flaps when mobilized, and the fact that the tissues are less compliant.

Recommendations
Planning and Technique
When planning the Singapore flap for vaginal vault reconstruction, one must not underestimate the amount of tissue that is required. In cases of introital stenosis, release should be performed first and the defect accurately measured. A flap design slightly larger than the defect will help combat inevitable shrinkage and restenosis.

In elevating the Singapore flap, dissection proceeds quickly, and it is not necessary to isolate and identify the source vessel. Therefore it is critical to maintain the base of the flap and not overdissect it. This can be accomplished by maintaining a 2 to 3 cm diameter area of attachment at the base that does not get undermined. The area overlying this is mobilized in the subcutaneous plane, thus preserving the pedicle.

Continued
I strongly recommend opening a path from the donor site to the recipient site so a direct transposition can be performed. There is little to be gained by making a subcutaneous tunnel other than compression of the flap. After transposition of the flap to the defect, a gentle vaginal stent is placed within the vaginal vault to ensure proper distribution of the flap and to prevent hematoma or seroma. Care should be taken to avoid excessive pressure on the flap from this bolster.

Postoperative Care
It is important to keep the area clean postoperatively. I recommend bathing with direct cleaning of the area after 48 hours and daily thereafter. For the first 2 weeks, the vaginal stent can be removed for hygiene and then gently replaced by the patient. Because of the high degree of bacterial colonization in this area, one should have a high index of suspicion for cellulitis, which should be treated aggressively.

Complications
The main complications related to the Singapore flap are necrosis of the tip, wound dehiscence, introital stenosis, and redundancy at the rotation point. Delay of the flap can improve vascularity and limit problems with tip necrosis, especially when larger flaps are required. This should also be done when a Singapore flap is used in an area that has previously been irradiated. Wound dehiscence is managed conservatively with dressing changes allowing secondary healing. Introital stenosis can be managed with dilators or additional flaps. I strongly recommend leaving the areas of redundancy at the base of the flap at the time of initial transposition. This redundancy contains the pedicle blood supply and should be spared. I wait 4 to 6 months before considering revision, when the pedicle blood supply is less critical and the flap has settled.
Bibliography With Key Annotations


Vaginal agenesis is the most common congenital deformity of the female pelvis, and vaginal reconstruction remains a surgical challenge. There are various surgical and nonsurgical techniques described for the reconstruction of a neovagina. The authors used pudendal thigh flaps to reconstruct the vagina in 19 patients; 11 (58%) were diagnosed with Mayer-Rokitansky-Kuster-Hauser syndrome and 8 (42%) with isolated vaginal atresia. The flaps were raised on either side of labia and sutured to each other in midline to form a vaginal tube. This neovagina was inserted into the space between the rectum and bladder and anchored to the deep pelvic tissues. One year postoperatively, the patients’ mean vaginal length and width was 9.2 and 4.3 cm, respectively. This method of vaginoplasty is simple, safe, and reliable and has shown satisfactory functional and cosmetic results. The reconstructed vagina has a natural angle and is sensate in its lower part. No postoperative stenting or dilation is required.

The donor site in the groin can be closed primarily, and the scar is well hidden in the groin crease.


Necrotizing fasciitis is an aggressive, deep-seated infection of the fascia and subcutaneous fat with necrosis of the overlying skin, and it is a toxin-mediated disease. The aim of this study was to review 13 cases of necrotizing fasciitis of the perineum and the external genitalia with regard to the diagnosis, treatment, and methods of reconstruction of secondary defects. The study included 11 men and 2 women, 35 to 67 years of age. All patients presented to the plastic surgery unit with huge secondary defects of the urogenital region, upper thigh, and lower abdomen after being excised initially by general surgeons. Eight patients were treated with bilateral flaps, and the unilateral flap was used in two patients. The V-Y island fasciocutaneous flap, used to resurface the urogenital region after necrotizing fasciitis, is considered a new indication. The V-Y axial-pattern design of the flap is also considered a new modification, which enables the flap to be advanced and tailored nicely in the midline. The idea of using the V-Y-plasty design is raised because the perineum has a pair of symmetrical anatomic structures. In addition, this procedure conserves tissue and the flap donor site is closed primarily without tension. Both aesthetic and functional results were satisfactory.


The authors reported their experience with pudendal thigh flap reconstruction in five patients with congenital absence of the vagina. In all patients bilateral pudendal thigh flaps based on the posterior labial artery, a branch of internal pudendal artery, were raised on either side of labia. These were sutured in the midline and inserted into the neovagina created by dissection between the rectum and urinary bladder. Postoperative problems were minor, and the reconstructions achieved good anatomic and functional results.


Eleven adult cadavers (22 sides) were dissected under an operating microscope (10X). Microstructures, including perforating arteries, venae comitantes, vascular anastomoses, and cutaneous nerves, were measured with a sliding caliper (accurate to 0.2 mm). There were four relatively constant perforating arteries in the perineum: inguinal and perineal perforating branches of the superficial external pudendal artery, a perforating branch of the anterior cutaneous branch of the obturator artery, and a perforat-
ing branch of the lateral branch of the posterior scrotal (pudendal) artery. All four arteries were direct perforating branches. These perforating arteries and accompanying veins overlapped with each other and formed the upper, middle, and lower parts of the vascular anastomosis in the deep fascia above the adductor wall. There were four important cutaneous nerves in the region originating from the following nerves: the genitofemoral nerve, ilioinguinal nerve, posterior scrotal (labial) major nerve, and rami perineales nervi cutanei femoris posterioris. The perineum has abundant blood supply, venous return, and innervation. Because of its covert location and maneuverability, a perforator flap from this region is a good source of donor tissue for perineal reconstruction.


Scrotal defects resulting from many factors, including accidents, Fournier’s gangrene, and gunshot injuries, present difficulties in management and reconstruction. Antibiotic therapy must be given to all patients, and if necessary, vigorous debridement must be performed. Because of the abundant vascularity of the region, local wound dressing results in dramatically rapid recovery of the wounds. In unsuitable conditions that prevent primary closure of the scrotal skin, thigh flaps may be used. Proximally based neurovascular pudendal thigh flaps were used in 10 scrotal defects. The maximum dimensions of the elevated flaps were 20 by 15 cm. All donor areas were closed primarily. Satisfactory results were achieved in all patients, especially in terms of sensitivity.


To reconstruct a large defect of the vulva, the authors combined the gluteal fold and pudendal thigh flaps and made a bilobed flap. Using this gluteal fold pudendal thigh bilobed flap, they were able to reconstruct the vagina with sufficient depth and width. The surrounding skin defect was simultaneously reconstructed. Sensation was intact in all areas of the reconstruction. The sutured lines of both donor sites were hidden in the gluteal and inguinal folds. Thus the gluteal fold pudendal thigh bilobed flap seems to be ideal for reconstructing large vulvar defects.

Oosterlinck W, Monstrey S. The pudendal thigh fasciocutaneous flap to cover deep perineal defects, combined with reconstruction of the posterior urethra. BJU Int J 89:133–135, 2002.


Vaginal defects from oncologic resection present a complex array of reconstructive challenges. Increased use of adjuvant radiation and chemotherapy demands uncomplicated wound healing. Because patients are being diagnosed at earlier stages of disease and at younger ages, maintenance of sexual function and body image are fundamental goals. The authors provided an algorithmic approach to defect classification and flap reconstruction. Careful appreciation of the specific defect facilitates flap choice. There are two basic defect types: partial (type I) and circumferential (type II) defects. These defect types can be further subclassified: type IA defects are partial and involve the anterior and/or lateral wall; type IB defects are also partial, but involve the posterior vaginal wall. Type IIA defects are circumferential, involving the upper two thirds of the vagina; type IIB defects represent circumferential, total vaginal resection, most commonly following pelvic exenteration. Using this method of defect classification, three pedicled flaps can be used to successfully reconstruct the majority of defects: the Singapore (or pudendal thigh) flap, the rectus flap, and the gracilis flap. With appropriate flap choice and a multidisciplinary approach to patient care, rapid wound healing, restoration of the pelvic floor, and reestablishment of sexual function may be most reliably achieved.


The pudendal thigh flap or the Singapore flap is a versatile flap that can be used in the repair of rectovaginal fistulas. Apart from the potential problem of hair growth, this neurovascular flap proves to be surprisingly simple in technique. It is robust and has a high potential to produce normal or near-normal function.

Although the pudendal thigh fasciocutaneous flap is reliable for perineal reconstruction when small but is unreliable when large flaps are raised. Large flaps in particular are associated with an increased incidence of apical necrosis. Thorough descriptions of the vascular anatomy of this flap have been lacking from the literature; the authors aimed with their study to provide the anatomic basis for vascular problems and for techniques to maximize flap survival. Five fresh human cadaveric pelvis specimens were studied. Lead oxide injectant allowed radiographic and dissection analysis of the arterial anatomy of the integument of the perineum. A consistent pattern of vascular supply was found in all specimens. The blood supply to the pelvic floor was supplied sequentially by the posterior labial/scrotal arteries, cutaneous branches from the anterior branch of the obturator artery, and branches from the external pudendal arteries. These vessels ran close to the midline, medial to the pudendal thigh fasciocutaneous flap. The posterior labial/scrotal arteries were deep to Colles’ fascia and the branches from the obturator artery and external pudendal arteries were located superficial to Colles’ fascia. The study has demonstrated that the pudendal thigh fasciocutaneous flap is a three vascular territory flap and that the pedicle is situated close to the midline. This could explain why regions of the pudendal thigh fasciocutaneous flap may have a potentially precarious blood supply and suggests that the flap should be designed more medially. Given the third territory of supply to the apex of the flap, a delay procedure may help to avoid flap necrosis.


To reconstruct the perineal region, including the urogenital and anal triangle, which differ from each other in tissue characteristics and function, the authors applied pudendal artery perforator flaps with a bilobed flap design. This design improved the arc of flap rotation and the mobility of the flap so it could cover wide and deep defects. Moreover, it could preserve the characteristics of each triangle. This study enrolled a total of 15 female patients who had undergone perineal reconstruction with pudendal artery perforator flaps: 7 of them had vulvar cancer; 7 had extramammary Paget’s disease; and 1 had a rectovaginal fistula. Bilobed flaps were used in 9 patients, and unilobed flaps were used in 6. All flaps survived during the entire follow-up period (average 4.6 months). Flap sizes ranged from 3 by 4 cm to 13 by 12 cm. The reconstructed areas were in good functional and aesthetic conditions. The bilobed pudendal artery perforator flap can preserve the functional, morphologic and cosmetic characteristics of the defect area.


Complete urethral reconstruction in women is an extreme challenge for urologists. The authors reported a new approach using a modified neurovascular pudendal thigh (Singapore) flap for neourethral reconstruction in two patients. A Singapore flap was raised and transposed to the vagina in two patients whose urethras had been destroyed by several previous urogynecologic procedures. In one case, the flap was tubularized distally and anastomosed proximally to the bladder neck. In the second case, the flap was used to cover a urethroplasty inlay. At 24 and 27 months, respectively, the two flaps were viable and appeared to fulfill their designated roles. The first patient developed a bladder neck stricture 2 months after surgery, and urethral dilation was performed successfully. Urinary incontinence still remains an issue in one of these two patients, and further continence procedures have been used. It has been found that the neurovascular pudendal thigh flap, initially described for vaginal reconstruction, is an attractive technique to aid in complete female neourethral reconstruction. Further follow-up of patients is necessary to address the issue of continence.
Chapter 11

Abdominal Viscera

Certain reconstructive situations require the use of specialized tissues for a successful outcome, and the reconstructive surgeon has no anatomic bounds when accessing important donor sites. Surgeons’ comfort with general surgical principles allows the use of intraabdominal-based flaps to facilitate the reconstruction of difficult defects while minimizing donor site morbidity. Jejunal flap reconstruction has aided restoration of esophageal continuity without compromising the stomach or the esophagogastric junction, while omental tissue, with its unique vascular and immunologic properties, has proved to be a useful adjunct in head and neck, sternal, and even hand reconstruction.

Jejunal Flap
Omental Flap
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>The jejunum is the segment of bowel linking the duodenum with the ileum of the small bowel. The proximal segment should start a minimum of 30 cm from the ligament of Treitz.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>7 to 25 cm × 4 cm.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Absorption. Resection of a short segment of bowel will not affect intestinal absorption.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Bowel.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Branches of the superior mesenteric arterial arcades.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td>Autonomic and sensory fibers from the celiac and superior mesenteric plexuses.</td>
</tr>
</tbody>
</table>
Section 11A

ABDOMINAL VISCERA

Jejunal Flap

CLINICAL APPLICATIONS

Regional Use
- Cervical/thoracic esophagus
- Genitourinary

Distant Use
- Head and neck
- Thoracis

Specialized Use
- Vaginal reconstruction
- Bladder reconstruction
Fig. 11A-1  A, Relevant anatomy of the jejunal flap. The ligament of Treitz marks the point at which the duodenum becomes the jejunum and emerges from its retroperitoneal position. B, The jejunal segment for harvest is at least 30 cm from the ligament of Treitz and is based on the vascular arcade. Distal terminal ileum is avoided. C, Arterial supply and venous drainage. D, Innervation of the jejunum. The flap is deinnervated when harvested, although local peristaltic reflexes persist.

**Dominant pedicle:** Superior mesenteric artery
ANATOMY

Landmarks

The jejunum is the segment of bowel linking the duodenum with the ileum. It extends from the ligament of Treitz for a distance of 2.5 m (8 feet). The lumen diameter is 4 cm. The bowel segment lies inferior to the greater curve of the stomach and the transverse colon. It commences at the ligament of Treitz as the duodenum passes from its retroperitoneal position to become the jejunum below the body and tail of the pancreas. It lies in multiple folds before becoming the ileum approximately 2.5 m from the ligament of Treitz.

Composition

Bowel.

Size

7 to 25 cm × 4 cm.

Function

Absorption. Resection of a short segment of bowel will not affect intestinal absorption.

Arterial Anatomy

Dominant Pedicle  Segmental via branches of the superior mesenteric artery

Branches of the superior mesenteric arterial arcades that originate from the source vessel in the retroperitoneal space, passing up between the two leaflets of the mesentery. The vessels are encased in variable amounts of fat, depending on the individual’s weight. Each artery is accompanied by a vein. In the upper jejunum, the mesentery is short, and there is usually only one arch from which the vasa recta radiate outward like the spokes of a wheel. Distally, there are usually at least two or three major vascular arcades supplying the length of the jejunum. It is imperative that the interconnection of the vasa recta be confirmed by direct examination before committing to a given flap length.

Regional Source  Superior mesenteric artery.

Length  5 to 7 cm.

Diameter  2 to 2.5 mm.

Location  At the base of the mesentery, distal to the ligament of Treitz.

Venous Anatomy

There are single veins accompanying the arterial circulation; the average venous diameter is 2 to 2.5 mm, with fragile venous walls in some patients.

Nerve Supply

Autonomic and sensory fibers from the celiac and superior mesenteric plexuses.
Vascular Anatomy of the Jejunal Flap

Radiographic view

Fig. 11A-2

Dominant pedicle: Superior mesenteric artery (D)
FLAP HARVEST

Design and Markings
The flap is exposed either through a vertical upper midline abdominal laparotomy incision or through a laparoscopic approach.

Patient Positioning
The patient is positioned in the supine position for both flap harvest and inset. Given the potentially lengthy nature of these procedures, careful attention should be paid to protecting pressure points. Arms are usually tucked at the patient's sides.
GUIDE TO FLAP DISSECTION

The abdominal cavity is approached through either an open laparotomy incision in the upper midline, or via a laparoscopic technique. A suitable length of jejunum should be located within the first 30 to 60 cm of the ligament of Treitz. The length of the flap is determined by measuring the defect and the tissue need. For esophageal reconstruction, it is helpful to add at least 2 to 3 cm of flap length to allow creation of an external monitor segment. The bowel is held up to posterior illumination so the vascular arcades to the bowel loops can be seen. The appropriate arcades have been identified, and the anterior and posterior leaflets of the mesentery are carefully incised to create a wedge–shaped harvest of the contained vessels. All side branches extending across the mesenteric harvest should be ligated with vessel clips or cauterized with a Harmonic scalpel. Hemostasis must be meticulously secured, because mesenteric bleeders can result in catastrophic postoperative hemorrhage.

Once the wedge of mesentery with its contained vessels has been isolated, the bowel is prepared for resection. Anastomotic stapling devices are clamped across the desired transection points and are fired. This results in the isolation of the jejunal flap on its vascular pedicle. The stapled proximal and distal bowel ends are then brought together and anastomosed with anastomotic staplers to reconstitute small bowel integrity within the abdomen. The isolated bowel segment should be marked to identify the proximal and distal ends so that a prograde direction can be maintained when the bowel is inset into the esophagus. Once the recipient site is ready, the isolated jejunal segment can be transected at its pedicle base and transferred to the recipient site for microvascular anastomosis. Typically the flap is anastomosed to the internal mammary vessels. Following reestablishment of vascular flow to the jejunal segment, it can be sewn into the ends of the pharyngoesophageal defect to restore continuity of the esophagus. Whenever possible, it is useful to dissect a 2 to 3 cm segment of proximal jejunum on a single vascular arcade to exteriorize as a monitor of flap viability. Once the flap is deemed stable at 5 days, the external monitor segment can be tied off at the bedside and resected.
Abdominal Viscera

Fig. 11A-5
Exposure and isolation of mesenteric pedicle

Fig. 11A-6
Jejunal free flap with external monitor bowel segment attached for postoperative monitoring

Jejunal flap design

Enteroenterostomy to reestablish bowel continuity

External monitor bowel segment

Esophagus

Jejunal free flap
FLAP VARIANTS

- Segmental flap
- Jejunomesenteric flap

Segmental Flap
The jejunum is usually used as a complete tube for pharyngoesophageal reconstruction or vaginal reconstruction. Less commonly, it may be split along its antimesenteric border to create a larger patch to repair a partial esophageal defect or for intraoral lining.

Jejunomesenteric Flap
The jejunomesenteric flap is a combination of a short segment of jejunum carried on a wider segment of mesentery. Used for soft tissue coverage or fill. With this modification, a long segment (25 cm) of bowel is harvested. The central 8 to 10 cm is maintained as a bowel loop while the proximal and distal portions of bowel are discarded leaving mesenteric flanges carried on the same vascular pedicle. The bowel is used for interposition as usual, while the mesenteric components can be used for additional soft tissue cover.
ARC OF ROTATION
Because of its short pedicle length, the arc of rotation is somewhat limited. A pedicled flap may be used in short gut syndrome, vaginal reconstruction, or bladder reconstruction. Pedicled Roux-en-Y jejunal flaps have been described for cervical and thoracic combined esophageal reconstruction, often requiring additional microsurgical anastomosis in the neck to ensure vascularity. Generally, however, the flap is used as a free flap to the pharyngoesophagus.

FLAP TRANSFER
The flap is transferred to its recipient site based on usage. For vaginal and bladder needs, one must exercise care to avoid internal hernias by closing the mesenteric defects created. The serosa is used to help tack and support areas of inset or suture line. For cervical esophageal reconstruction, the flap is based on the location of the pharyngoesophageal defect. Usually these are upper third defects of the esophagus, but the flap may be interposed at any point along the length of the esophagus as needed. Because of pedicle length constraints, vascular anastomosis should be made within the immediate vicinity of the esophageal defect to provide a completely tension-free bowel repair. Any tension on the anastomotic lines will result in anastomotic leaks with the potential for mediastinitis.

FLAP INSET
For esophageal reconstruction, the proximal and distal bowel anastomoses are performed before the microsurgical anastomosis. A feeding tube should be placed before final closure.

DONOR SITE CLOSURE
Before closing the abdomen, the surgeon must repair the mesenteric defect within the donor site to prevent the risk of internal hernia formation. This is done with either catgut or Vicryl sutures, and care must be taken not to compromise the vessels remaining within the mesentery. Abdominal closure is performed as dictated by the surgical approach to the peritoneal cavity: midline laparotomy incisions are closed as a mass closure with permanent suture, whereas laparoscopic incisions are closed in layers with fascial repair.
CLINICAL APPLICATIONS
This 58-year-old man presented with a proximal esophageal fistula complicating colonic interposition grafting for esophageal cancer resection.

Fig. 11A-8  A, Preoperative view of patient with proximal esophagocolonic stricture after previous colon interposition. B, Intraoperative view of exposed proximal colonic anastomotic stricture resection. C, Jejunal interpositional flap sewn in with a proximal bowel segment for use as a perfusion monitor on the skin surface. D, Preoperative radiograph demonstrating extensive tight stricture of colonic interposition segment. E, Postoperative radiographs of free barium passage down healed jejunal interposition. (Case supplied by GJ.)
This 53-year-old man had a history of squamous cell carcinoma of the pharynx for which he had been treated 8 years earlier by resection and reconstruction with a radial forearm free flap. He presented with a recurrence in the pharynx and required a completion laryngopharyngectomy. He underwent reconstruction with a free jejunal transfer as a free flap.

Fig. 11A-9  A, The bowel was prepared for transfer while still perfusing in the abdomen. The measurements from the defect dictated the length. An extra segment was harvested on the same pedicle to use as an external monitoring segment. If having this segment were to in any way compromise the transplant or put tension on the anastomosis, it could be removed. B, The jejunum was inset and perfused. The monitoring segment was positioned laterally. The buried flap can be monitored by observing the perfusion of the monitoring segment or by Doppler examination of the exposed pedicle. It was ligated and removed at the bedside on postoperative day 5. C, On day 10, a gastrograffin swallow is performed. If no leaks are noted, a definitive barium study may be performed, or the patient may be started on a soft diet. Not uncommonly, a small leak is noted, and feeding is delayed for an additional 2 weeks, then started without further studies. Shown here is a normal lateral barium study at 10 days postoperatively. (Case supplied by MRZ.)
This 21-year-old had a corrosive injury of the esophagus after swallowing an alkaline solution. He underwent thoracic and cervical esophagus reconstruction with a pedicled colon flap at another institution. He presented to our institution 2 years later with a stricture spanning 7 cm at the cervical esophagus region.

**Fig. 11A-10**  
A, Preoperatively the patient had a feeding tube and a neck scar. He underwent attempted dilations without success. He was taken to the operating room, and the neck and upper part of the substernal region were explored. The proximal end of the cervical esophagus was located at an area with normal mucosa.  
B, Distally, normal-appearing colon was identified in the substernal area.  
C, A free jejunal flap was harvested and used to span the defect. The jejunal artery and vein were anastomosed to the transverse cervical artery and external jugular vein, respectively.  
D, The flap is shown inset and viable. The patient healed and was eating a normal diet after 3 weeks.
About 5 months later, the patient presented with discomfort in the upper left chest region. A CT scan revealed a small fluid collection and a fistula tract from the cervical esophagus–jejunum anastomosis, with no connection to the skin. The patient underwent exploration of the area.

**Fig. 11A-10**  
E, The fistula tract was identified and debrided, and the tract was closed. F and G, A pectoralis major muscle was harvested and used to reinforce the repair and obliterate the tract. H and I, The patient healed and was able to resume a normal oral diet after 4 weeks. (Case courtesy Samir Mardini, MD.)
This 56-year-old man underwent resection of part of the cervical esophagus, resulting in a circumferential esophageal defect.

Fig. 11A-11  A, A portion of the cervical esophagus was resected. B, A segment of jejunum was harvested from an area 30 cm distal to the ligament of Treitz. C and D, The proximal and distal ends of the jejunum were anastomosed to the proximal and distal ends of the defect, reconstituting continuity of the gastrointestinal tract. A long monitor loop was kept in place. (We no longer use a monitor loop since we began using the implantable Doppler.) A monitor loop does not need to be more than 6 cm in length. The jejunal vessels were anastomosed to the transverse cervical artery and external jugular vein. E, Ten hours postoperatively, a dramatic change in color and turgor was noted on the monitor loop. The patient was taken to the operating room emergently, and the artery and vein were evaluated. There was a thrombus in the artery at the level of the anastomosis. F, The anastomosis was revised, and the flap reperfused nicely. The patient healed uneventfully and was able to tolerate a regular diet 3 weeks postoperatively. (Case courtesy Samir Mardini, MD.)
Abdominal Viscera • 11A: Jejunal Flap

Pearls and Pitfalls

- The proximal division of the jejunum should be made distal enough from the ligament of Treitz to allow creation of an easily accessible, tension-free anastomosis of the remaining bowel following flap harvest.
- More distal harvest allows for the incorporation of more vascular arcades as the mesenteric length increases.
- Every effort should be made to ensure that all bowel edges, both in the abdominal donor bowel and in the flap margins, have adequate vascular inflow. This can be greatly facilitated by the use of indocyanine green fluorescence imaging. Repair of poorly vascularized bowel ends will result in anastomotic leaks with potentially life-threatening complications.
- The peristaltic direction of the donor segment of bowel should be marked to ensure prograde peristalsis in the reconstructed esophagus once repair has been completed.
- A nasogastric feeding tube should be passed through the flap lumen before bowel anastomosis.
- Leaks in the transferred segment are less likely if a stapled anastomosis can be performed at each end. This can be difficult to achieve within the tight confines of the mediastinum and if a hand-sewn repair is performed, it must be done meticulously, preferably with preplacement of all sutures before these are tied down. This approach will minimize leaks.
- The mesenteric defect within the donor site must be repaired carefully to prevent internal hernia formation.

EXPERT COMMENTARY
Samir Mardini, Karen Kim Evans, Hung-Chi Chen

Indications
In the early 1900s, the jejunum was used as a pedicled flap for reconstruction of the thoracic esophagus. Once microsurgical reconstructions became possible, surgeons began to adopt the jejunal flap as a free flap because of its unique anatomic advantages. It is tubed, lubricated, and has peristaltic activity; moreover, it has a reliable blood supply, and its harvest is simple and expedient. The jejunal flap has proved successful in the reconstruction of various types of complex defects, including the esophagus and vagina.

Advantages and Limitations
The jejunal flap provides a wealth of advantages: the tubed nature of the jejunum and its peristaltic activity provide functional benefits when used for pharyngeal and esophageal reconstruction. Its intrinsic peristaltic activity may help propel a food bolus, and its tubed structure minimizes complications because of the low number of suture lines necessary to complete the reconstruction. Flap harvest is quick and simple, and the jejunal diameter approximates that of the esophagus.

As a free flap, the vascular pedicle can be lengthy (up to 15 to 20 cm), with vessels of suitable external diameter (artery 1.5 to 2.5 mm; vein 2 to 4 mm). The jejunum can be considered relatively sterile, with minimal potential of developing diseases, such as cancer.

Continued
or atypical polyps. The accompanying mesentery can be employed to cover vital neck structures and can provide a suitable bed for skin grafting. The length of jejunum available for transplantation ranges from 7 to 25 cm, based on one pedicle.

As a pedicled flap, the jejunum can replace the entire length of the esophagus; however, in those cases it becomes necessary to supercharge the arterial inflow and venous outflow in one or two places. The jejunum can be split along its antimesenteric border, creating a flat and well-vascularized mucosal structure that can function as a patch. This patch of jejunal tissue is suitable for reconstruction of partial circumferential defects or for providing oral lining.

A jejunal flap can be harvested based on one vascular pedicle and split into two segments that can be used to reconstruct two different defects or to provide a monitor segment. This flap is ideal for vaginal reconstruction, because it is lubricated and tubular.

The surgeon must also be aware of disadvantages associated with the use of this flap. In experimental models, the jejunal flap may be more susceptible to the harmful effects of ischemia. Clinically, an ischemic time of about 2 hours can be tolerated without permanent effects on the outcome of the reconstruction.

The patient will require either a laparotomy or a laparoscopically assisted approach to the abdomen—techniques that carry their own inherent risks. Reports have shown a mortality rate between 2.4% and 5% when using jejunal flaps for reconstruction of esophageal defects. This rate is similar to using gastric pull-up and colonic interposition and may be related to the type of patient population and the nature of the disease process itself rather than the type of flap used. Fistula rates continue to range between 1.8% and 30%, which in many series is lower than that of skin flaps used for the same purpose.

Anatomic Considerations

The jejunum has a segmental blood supply. The overall length of the pedicle, the jejunal artery (arising from the superior mesenteric artery), may appear to be between 15 and 20 cm, but this length is shortened by the vascular loop configuration of the blood supply. There is a complex branching network composed of multiple, consecutive, tiered vascular loops called arcades (see Fig. 11A-12). The primary order arcades run parallel to one another within the layers of the mesentery. These parallel vessels divide in two branches, one ascending and one descending branch, that course parallel to the intestine. These branches then unite with the adjacent branches coming from the closest jejunal arteries, thus forming an anastomotic arcade. From the last arcade (which is the last arch parallel to the intestine) arise the vasa recta, which form the direct and terminal blood supply to the jejunum.

**Fig. 11A-12** The vascular arcades within the mesenterium; a closeup view of the terminal branches, the vasa recta.
The vasa recta are terminal vessels measuring approximately 4 to 6 cm. One or two vasa recta supply a distinct area of jejunum (approximately 1 cm per vasa recta unit). It is very important to note that the veins within the mesentery are thin and fragile, and care must be taken during harvest, especially in larger patients with a thick mesentery.

**Personal Experience and Insights**

The jejunal flap serves a distinct role in reconstructive surgery. We have used it extensively in the reconstruction of cervical esophageal defects and total vaginal reconstructions. We have also found it to be useful in patching a defect in the esophagus after partial resection or after stricture release. Skin flaps provide a reasonable alternative for reconstructing defects requiring a patch of tissue so that the abdominal cavity is not violated. However, if intraabdominal surgery is performed for other reasons, we favor harvesting the jejunum, filleting it open and using it as a patch. We have used the jejunal flap as a pedicled flap to patch partial vaginal defects.

In patients who require total esophageal reconstruction who do not have a pedicled stomach or colon flap available, the pedicled jejunal flap can be a great solution. When using the jejunum to reconstruct a hypopharyngeal defect, the proximal end can be double-barreled to create a better size match to the proximal end. We have used the jejunum in other types of reconstructions, such as creation of a voice tube and intraoral lining when radiation has created severe intraoral dryness.

Controversy remains as to whether the benefits of intestinal flaps outweigh the risks for esophageal reconstruction compared with skin flaps. In our experience, patients undergoing esophageal reconstruction with intestinal flaps have better functional outcomes in regard to swallowing function, fistulas, and stricture formation. When a voice prosthesis is placed between the trachea and neoesophagus (jejunum or skin) for voice rehabilitation, patients have a less “wet” voice if skin flaps are used. Entering the abdomen is in itself a low-morbidity procedure, particularly when laparoscopic techniques are used. However, harvesting the anterolateral thigh perforator flap has lower donor site morbidity compared with the jejunal flap, particularly if the patient has previously undergone major abdominal surgery. In those cases, using the anterolateral thigh flap might be more reasonable.

We do not favor the use of the radial forearm flap in patients who do not absolutely require us to use it, because we have found that the donor site scar is very unsightly and can be a source of problems in areas where cold weather is predominant.

*Continued*
We have seen many surgeons who begin performing microvascular reconstructions in their own practice and abandon the use of jejunal flaps early in their career. We attribute this to having one or two failures early on, which have discouraged them from continuing to use this flap. We think that these failures occur from simple and avoidable technical problems. We will attempt to outline some of them based on our experience with over 500 intestinal transfers including jejunum and colon:

- Flap harvest is simple and quick. However, it must be performed with special attention at every step. Small bleeding vessels can create a hematoma within the mesentery that can disturb blood supply to the jejunum and/or distort the anatomy and ultimately create a kink in the main pedicle.

- Any traction on the pedicle must be completely avoided, because it can create unnoticed intimal damage and eventual spasm and thrombus formation. Therefore vessel loops are avoided; they can produce uncontrolled pulling on the pedicle and cause kinking when the flap is left in position in the abdomen after harvest is complete. We have seen one flap undergo complete necrosis after the surgeon left the vessel loops in place attached to a mosquito forceps after completely isolating the flap and the pedicle and moving to the neck to find recipient vessels. The surgeon came back to detach the flap 2 hours later and found the flap to be cyanotic and nonusable.

- The pedicle must not be twisted after the flap has been completely dissected and is still in the abdominal cavity. The surgeon should pay close attention to the position of the flap after complete isolation of it and the pedicle if it is to be left in the abdomen while another part of the procedure is performed.

- The proximal part of the pedicle should be dissected as the last step in the procedure, because this will help to avoid tension on the vessels (the mesentery can take some of the tension). Dissection of the proximal part of the vein in particular can have bleeding, usually in a deep hole, and it is better to have everything completely ready so that the vessels can be clamped and ligated in case bleeding is encountered.

- Abdominal donor site morbidity can be minimized by performing a meticulous anastomosis of the proximal and distal anastomosis of the jejunum when restoring intestinal continuity and meticulous closure of the abdominal wall.

- The defect and recipient vessels must be completely ready for inset and vascular anastomoses before flap harvest is completed to minimize ischemic time.

- The more challenging bowel anastomosis should be performed before the microvascular anastomosis is done. We have started anastomosing the proximal end first, performing the microvascular anastomosis, then the distal anastomosis. After restoring blood flow to the flap, the jejunum undergoes physiologic lengthening, and one can more accurately assess the appropriate length. Now we sometimes place the jejunum in the correct position, secure it in place using external sutures, secure the mesentery in position using 5-0 absorbable sutures, perform the microvascular anastomosis, then perform the proximal and distal anastomosis of jejunum to the esophagus. The key is not to allow the pedicle to move during the bowel anastomoses; otherwise, arterial spasm ensues, and a thrombus will form.

- When performing the microvascular anastomosis, the vein is anastomosed first, the clamps are removed, and then the artery anastomosis is performed. The artery can be anastomosed first; however, the clamps should not be released until the vein anastomosis is complete. The jejunum does not tolerate venous congestion as well as other types of tissue.
• Strictures can be lessened by performing oblique anastomoses or inserting a segment of vascularized tissue that widens the junction.
• We place stents that traverse the flap. One is used to decompress the stomach, and the other is placed with the holes positioned within the lumen of the jejunum. The key is not to allow swelling in the jejunum. If this happens, distortion of the flap may occur, which can change the position of the pedicle and possibly create a kink.
• The closure should be very loose over the jejunum. One should not hesitate to place a wet dressing or a skin graft (no bolster).

Fig. 11A-14 Constriction and stenosis can be prevented by spatulating the anastomosis. A, End-to-end anastomosis is begun as usual. B, Before finishing the anastomosis, the surgeon opens the jejunum longitudinally. C, This opening spreads and allows inset of the redundant pharynx or esophagus in a Y-to-V fashion. D, The final closure has a larger diameter than the jejunum and thus a circumferential scar that would constrict is avoided.

Recommendations

Technique

Midline abdominal incisions are used. After entering the abdominal cavity a segment of jejunum is identified for harvest. This segment is the second or third loop, which usually begins 25 to 30 cm distal to the ligament of Treitz. The segment is then harvested based on the second or third jejunal artery. The proximal and distal ends must be marked so that the segment is transferred in the same isoperistaltic, anatomic orientation. We usually place one suture on the antimesenteric side at the proximal end of the flap and two sutures on the antimesenteric side at the distal end of the flap to identify the proximal and distal ends.

For reconstructions requiring a pedicled jejunum, the fourth jejunal loop is identified as the distal part of the flap to be harvested. The third jejunal artery is ligated and divided close to its origin from the superior mesenteric artery, and both the third and fourth vascular pedicles can be used for supercharging. If the reconstruction does involve the third and fourth loop and two vascular pedicles are available for supercharge, the artery and vein of one of those pedicles are sutured first to neck vessels (transverse cervical or superior thyroid artery and external jugular vein) or chest vessels (internal mammary artery and vein), and the color of the flap is monitored. If color is good, one can avoid anastomosing the second vascular pedicle. The mesentery of the jejunum is then divided at the serosal border between the second and third jejunal artery, allowing the conduit to completely unfurl. This straightens the sinusoid turns in the small bowel caused by a naturally foreshortened mesentery. Any length of jejunum from 7 to 25 cm may be transferred on one vascular pedicle. The bowel lumen diameter is 3 to 5 cm.

Continued
After a midline laparotomy is done, the site of jejunal transection is marked either by sutures or with methylene blue. One must remember to identify the proximal portion of the jejunal segment (we use sutures, as described above) to perform the inset in an isoperistaltic position. The mesentery is scored with electrocautery at a low setting, from the bowel margin toward the center to expose the vascular pedicle. The mesentery is completely divided on each side and the vasa recta are then selectively clamped, ligated, and transected. In this way, a fan-shaped segment of mesentery attached to the jejunal segment is dissected and attached only to the donor vascular pedicle. Special care must be taken in patients with extensive mesenteric fat to avoid damaging branches of the mesenteric vessels. Vessel loops are not recommended, because they produce spasm and trauma to the pedicle vessels.

The bowel is then clamped using atraumatic bowel clamps both proximally and distally at the sites previously marked. The jejunal segment is isolated on a single jejunal artery and vein and is observed for adequate perfusion and peristalsis. Harvest of the bowel is performed using standard general surgery stapling devices, and intestinal continuity is reestablished using either side-to-side or end-to-end anastomoses.

Under loupe magnification, the jejunal artery and vein, arising from the superior mesenteric vessels at the root of the mesentery, are identified and dissected free from the surrounding tissues. Careful dissection of the jejunal vein is essential, because the wall is thin and fragile. The dissection begins from the superior mesenteric vessel toward the mesenteric border of the jejunal segment, at the sites of future proximal and distal bowel transection. We reserve dissection of the artery and vein at its proximal end until the end of the flap harvest, when the flap is completely ready for transfer and the recipient site is prepared. This allows immediate clamping, transection, and transfer of the flap if bleeding problems occur.

When the recipient site dissection is complete, the jejunal segment is harvested from the abdomen after dividing its blood supply at its origin from the superior mesenteric vessels. The jejunal artery at the donor site is tied and suture ligated.

Avoidance of Complications and Postoperative Care

1. Choose a large recipient vein. For head and neck reconstruction, choose a large branch off the internal jugular, or use the external jugular. The jejunal vein can also be sutured in an end-to-side fashion to the internal jugular vein if the other two options are not available.

2. Work fastidiously and decrease ischemic time. Expose the recipient vessels and prepare the defect before dividing the flap pedicle. Once this is done, the jejunal flap can be transferred. If warm ischemic time is prolonged, the detached jejunal segment can be cooled by a double-lumen glass tube placed within the bowel lumen. Cooled saline solution (4°C) is run continuously through the tube. (This is rarely necessary in our practice, because we are able to maintain ischemic time at less than 2 hours.) The intestine segment is covered with laparotomy sponges moistened with normal saline solution. We anastomose the vein first, clamps are released, and the arterial anastomosis is performed. If the arterial anastomosis is performed first, we prefer not to release the vascular clamps until both the artery and vein anastomoses are completed. Damage to the intima can occur if the vascular clamp is in place for a prolonged period (over 1 hour). The arterial clamp is not released before performing the venous anastomosis because the jejunal mucosa does not tolerate venous congestion very well, and permanent damage can occur.
Abdominal Viscera • 11A: Jejunal Flap

3. Create a watertight closure, especially in head and neck cases. Use a two-layered closure between the jejunal segment and pharynx and ensure proper positioning after surgery to prevent hyperextension of the neck. After the procedure, the patient must avoid violent coughing, which can damage the closure.

4. Avoid strictures. We usually increase the diameter of the esophagus by making a small cut at the thoracic esophagus and use sutures instead of a stapling device for inset. Insert two intraluminal drains for stenting and drainage. If a second-layer anastomosis cannot be performed, we use excess mesentery to seal off the upper and lower anastomotic sites. Primary healing is important for future function, and a leak will cause inflammation and later stricture.

5. Avoid tight closure of the neck wound. If necessary, a local flap (deltoplex or pectoralis major) can be used for coverage, or the intestine is left uncovered and wet-to-dry dressings are used. Alternatively, a skin graft can be placed on the exposed segment of jejunum without a bolster dressing. External compression can compromise the blood supply.

6. Place drains. We place drains in the neck before closing the skin. Nonsuction drains are used on the side of the recipient vessels, and bulb suction drains are used on the side opposite the recipient vessels. In addition, we ask the nurses to pay close attention to suctioning saliva from the patient’s mouth for the first 2 or 3 days. Saliva accumulation can cause distention of the jejunal segment.

Reference


Bibliography With Key Annotations


This paper reviewed the authors’ experience with 15 cases of salvage reconstruction of the esophagus after prior cancer treatment or aortoesophageal fistula; the cervical esophagus was reconstructed in five cases, and the cervicothoracic esophagus in 10. In four cases of cervical esophagus and six of cervicothoracic esophagus, free jejunum transfer was performed; a thoracic esophagus was also reconstructed with pedicled alimentary tract transfer (colon interposition or jejunal pull-up) with vascular supercharge in four cases. In one case, a cervical esophageal defect was reconstructed with a latissimus dorsi myocutaneous flap. A deltopectoral flap to cover the skin defect was used in three cases. In three cases, a second salvage operation was necessary because of flap necrosis caused by unreliable recipient vessels resulting from scar formation and persistent inflammation. Successful restoration of the esophagus and oral alimentation was achieved in 11 cases.


This study evaluated long-term functional outcomes following pharyngolaryngectomy and free jejunal reconstruction. Nineteen patients, each undergoing a pharyngolaryngectomy with free jejunal graft, were included. Each had a primary tracheoesophageal puncture for insertion of an indwelling voice prosthesis for speech. Functional outcomes of speech and swallow were assessed by a qualified speech pathologist. The impact on patients’ quality of life was assessed under four domains: impairment, disability, handicap, and well-being. The mean time period to follow-up was 4 years. Eighteen of the
19 patients were tolerating an oral diet, with one patient reliant on percutaneous endoscopic gastrostomy feeds. Seventeen patients (89%) were assessed as having no—or only a mild degree—of dysphagia, with no evidence of aspiration. Fifteen of the 19 patients were using tracheosophageal speech for communication with 11 (73%) having no—or only a mild degree—of dysphonia. Patients assessed as having no evidence of dysphagia or dysphonia reported reduced levels of handicap and distress compared with patients experiencing any degree of dysphagia or dysphonia.


The MD Anderson Cancer Center team presented an extensive comparison of 57 circumferential pharyngoesophageal reconstructions with an anterolateral thigh flap in 26 patients performed by a single surgeon or a jejunal flap in 31 patients performed by six experienced surgeons between 1998 and 2004. Total flap loss occurred in one (4%) and two (6%) patients, fistula rates were 8% and 3%, and stricture rates were 15% and 19% in the anterolateral thigh and jejunal flap groups, respectively. Despite the limitations of comparing a single surgeon’s results with those of multiple surgeons, the anterolateral thigh flap appears to offer better speech and swallowing functions and quicker recovery and to be more cost effective than the jejunal flap for pharyngoesophageal reconstruction. The complication rates were similar.

Clinical Series


The authors presented their experience with 20 patients who underwent esophageal reconstruction with free jejunal transfers. Sixteen were successful for a success rate of 80%. Complications included an unusual case of balloon-like distention of the cervical portion of the transferred jejunum. The authors provided tips to avoid complications and improve success rates.


The authors presented their 4-year experience in 17 patients undergoing free jejunal transfer for reconstruction of the cervical esophagus and pharynx. Complications in 8 of their 17 patients included tracheosophageal fistula, oral cutaneous fistula, and three flap failures.


The authors described their experience with four patients who underwent pharyngolaryngoesophagectomy and reconstruction. In two patients a jejunal free flap was used and in two patients colon was used. All the reconstructions were successful. One patient in the jejunal group developed an intussusception in the abdominal donor site. The authors believe that the jejunum is preferable to the colon because harvesting is simpler. However, they pointed out that their experience was too small to reach any definite conclusions.


The authors reviewed 134 patients who underwent esophageal resection and reconstruction with stomach, small intestine, or right transverse or left colon interposition. The reconstructions were performed between 1946 and 1965. Although microsurgical reconstructions were performed, the authors compared the results of each type of viscera. They concluded that the small bowel appeared to provide the best long-term functional results.


A long length of jejunum was used to reconstruct the cervical esophagus in one patient. The recipient vessels were the thoracoacromial artery and the cephalic vein. The jejunum was covered with a split-thickness skin graft.

Jejunal free grafts transferred by microsurgical techniques were used to salvage pharyngoesophageal strictures and fistulas. The authors reported on 55 patients, the majority of whom were treated for squamous cell carcinoma or the complications of combined radiation and operative therapy. There were six graft failures for a success rate of 90%. There was a 5% (3 patients) operative mortality. Fourteen patients had radionecrotic fistulas (4 patients) or strictures (10 patients).


This was the first report of a “large” series of 22 cervical esophageal reconstructions in which free jejunum was transferred via a microsurgical technique using an operative microscope and a 9-0 nylon suture on a microsurgical needle. Seventeen procedures were performed for reconstruction of the oropharynx, hypopharynx, and cervical esophagus, and five procedures were performed to provide lining in the oral cavity. There were two failures for an overall success rate of over 90%.


A patient with a hard palate defect underwent reconstruction with iliac crest bone, which was covered with a segment of free revascularized jejunum.


This was a very early report on two successful esophageal reconstructions using jejunum. The artery of the free jejunal segment was sutured end-to-side into the external carotid artery with a continuous 7-0 black silk suture. The vein was sutured end-to-side into the internal jugular vein with a similar suture. Both reconstructions were successful.


Sixty-six patients with carcinoma of the hypopharynx or cervical esophagus underwent reconstruction consisting of a free radial forearm tubed flap, free jejunal transplantation, or a gastric pull-up procedure. The authors concluded that the radial forearm flap is the safest, but they recommended the free jejunum as the best method of reconstruction.


The authors described a reliable method of monitoring free jejunal flaps. A small portion of the jejunum was isolated on a branch of the jejunal artery and placed outside the area of reconstruction so that it could be monitored directly during the postoperative period.


The author described a case of total thoracic esophageal reconstruction from the neck down to the stomach using a length of jejunum with an intact mesenteric pedicle in the abdomen and a second “microassist pedicle” sutured end to end to the internal mammary vessels using 5-0 silk. A remarkable single-stage reconstruction was reported.


The authors used the new technique of manofluorography to evaluate swallowing. This technique provides simultaneous display of manometry and videofluoroscopy to evaluate swallowing. They studied 10 patients who had undergone total laryngopharyngectomy and reconstruction with either a microsurgical jejunal free graft or a gastric pull-up procedure. Factors that enhanced swallowing in these patients were the presence of a widely patent graft and an intact swallowing reflex. Conversely, factors that impaired swallowing included stricture, jejunal peristalsis, impaired lingual coordination,
and stenosis at the anastomotic sites. The authors noted that jejunal peristalsis is not synchronized with the delivery of the bolus from the oral cavity; consequently this can obstruct the bolus.


The authors reviewed their 5-year experience with 56 pharyngoesophageal reconstructions. Twenty-seven patients underwent reconstruction with skin flaps with or without underlying muscle and 29 underwent reconstruction with a free jejunal graft. Two thirds of both groups received radiation therapy. In the group with skin flap reconstruction 8 of 27 patients developed fistulas. This incidence increased in those patients who had preoperative irradiation. In contrast, none of the patients who underwent free intestinal segment reconstruction developed a fistula. The flaps included the pectoralis myocutaneous, latissimus myocutaneous, and deltopectoral flaps. The free segments of bowel were exclusively jejenum.


In this extensive review of the first 10 years of experience with microsurgical tissue transplantation, the author covers various donor sites, including the jejenum. Historical aspects of clinical applications were discussed.

**Flap Modifications**


Pharyngoesophageal reconstruction was reported in two patients. In each patient two separate sets of vascular anastomoses were required, one in the neck and the other in the midsternum, to reconstruct a long length of the pharynx and esophagus. In the first patient, a single loop was used; in the second patient, two separate segments were used to avoid redundancy.


This case report demonstrated a technique for enlarging the lumen of the transferred jejenum by splitting the wall of the intestine longitudinally, folding it, and suturing it to double the size.


The authors described an inverted J-shaped jejunal funnel that is prefabricated to enlarge the proximal stoma of a free jejunal transfer to overcome size discrepancies between the superior pharyngeal defect and the jejenum.


Miller described the technique for endoscopic harvest of the jejenum. The technique is being refined and developed.


Reconstruction of the cervical esophagus with the jejenum and contiguous mesenteric flap was described for the protection of vascular and mucosal anastomoses and the provision of soft tissue coverage.

**Complications**


The authors’ 10-year experience with 96 jejunal free flaps was described. Complications included 13 operative failures: arterial thrombosis (4), venous anastomotic problems (4), fistula and infection in the neck (1), carotid blowout (1), psychosis and avulsion of the bowel (1), and unknown cause (2). In seven patients a second attempt at salvage of jejunal flaps was successfully performed in five patients. There were five deaths (6%) in the perioperative period. Of these, one was directly attributed to graft failure. Eight abdominal complications required reoperation, including wound dehiscence (4), small
bowl obstruction (1), Mallory-Weiss tear (1), gastrectomy tube leak (1), and acute gastric dilatation (1). The authors concluded that significant palliation and a high rate of restoration of function are possible with free jejunal autografts and emphasized careful patient selection to decrease operative morbidity and mortality.


The authors reviewed 101 patients who underwent 111 free jejunal transfers. The absolute failure rate was 13.5%. Thirty-three patients had pharyngocutaneous fistulas; 20 of the patients had previous radiation therapy. Of those patients with fistulas, 15 patients had a spontaneous closure and nine other patients required surgical correction. The overall mortality rate was 5%. Eighty-three percent of the patients had adequate restoration of swallowing.


In a discussion of hypopharyngeal stenosis after total laryngectomy, the authors concluded that the overriding factor in the incidence of hypopharyngeal stenosis appears to be the performance of partial pharyngectomy and primary closure. They therefore advocate prevention of this complication through the reconstruction of partial pharyngectomies with new tissue, including a free flap or other distant tissue. They described their experience with the jejunum in 24 patients. In this group of patients they reported a 12% incidence of fistula formation.


In this extensive review the authors reported their experience in the treatment of hypopharyngeal cancer, its complications, and mortality. They also reviewed the literature, comparing complication rates and mortality following different methods of pharyngoesophageal reconstruction, including free jejunal grafts. In their series of 362 patients with squamous cell carcinoma of the hypopharynx, the hospital mortality was 25%. The mortality increased in those who had undergone previous radiation therapy and those who were in poor general condition. The mortality was higher for visceral, stomach, or colon transposition than for skin flap reconstruction. The hospital death rate for patients undergoing free microvascular grafts in the literature was 17.8%.
ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>The omentum is a well-vascularized apron of fat suspended from the greater curve of the stomach.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>30 to 40 cm × 30 to 60 cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>The omentum arises from the greater curvature of the stomach with secondary attachments to the anterior aspect of the transverse colon.</td>
</tr>
<tr>
<td>Function</td>
<td>Adheres to and walls off areas of inflammation within the peritoneal cavity. It serves as a secondary fat storage area.</td>
</tr>
<tr>
<td>Composition</td>
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<tr>
<td>Flap Type</td>
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<td>Dominant Pedicles</td>
<td>Right gastroepiploic artery and vein; left gastroepiploic artery.</td>
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<td>Nerve Supply</td>
<td>Autonomic supply from the splanchnic nerve plexus.</td>
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Section 11B

ABDOMINAL VISCERA

Omental Flap

CLINICAL APPLICATIONS

Regional Use
- Chest
- Trunk
- Scalp
- Extremity

Specialized Use
- Cheek (in Romberg’s hemifacial atrophy)
ANATOMY OF THE OMENTAL FLAP

Fig. 11B-1

**Dominant pedicles:** Right gastroepiploic artery; left gastroepiploic artery
ANATOMY

Landmarks
The omentum is a large, well-vascularized sheet of fat suspended from the greater curvature of the stomach. It forms the anterior wall of the lesser sac between the stomach and transverse colon and drapes over the small bowel inferiorly for a variable distance. Its thickness ranges from 3 to 10 mm, depending on the person’s weight. It can extend inferiorly as far as the pelvis.

Composition
Fat.

Size
30 to 40 cm × 30 to 60 cm.

Origin
The omentum arises from the greater curvature of the stomach with secondary attachments to the anterior aspect of the transverse colon. It hangs as a pendulous fatty apron covering the underlying small bowel to a varying extent and may reach to the pelvis in some individuals.

Function
The omentum has been called the guardian of the abdomen, an allusion to its ability to adhere to and wall off areas of inflammation within the peritoneal cavity. It may have a weak immune function, and it serves as a secondary fat storage area. The attachments of the omentum between the stomach and the transverse colon reduce the likelihood of spontaneous gastric volvulus.

Arterial Anatomy (Type III)

Dominant Pedicle  
Right gastroepiploic artery

Regional Source  
Gastroduodenal artery and vein.

Length  
6 cm.

Diameter  
2 to 3 mm.

Location  
Derived from the gastroduodenal artery beneath the first portion of the duodenum.

Dominant Pedicle  
Left gastroepiploic artery

Regional Source  
Splenic artery and vein.

Length  
4 cm.

Diameter  
2 mm.

Location  
Arises from the splenic artery on the proximal portion of the greater curvature of the stomach within the splenocolic ligament.

Venous Anatomy

Single veins accompany the arterial circulation; the average venous diameter is 1.5 to 3 mm. The right gastroepiploic vein is a branch of the superior mesenteric vein. The left gastroepiploic vein is a branch of the splenic vein.

Nerve Supply

Autonomic supply from the splanchnic nerve plexus.
Vascular Anatomy of the Omental Flap

Radiographic view

Fig. 11B-2

Dominant pedicles: Right gastroepiploic artery (D1); left gastroepiploic artery (D2)

FLAP HARVEST

Design and Markings
The flap is exposed through a vertical upper midline abdominal laparotomy incision, a diaphragmatic approach, or a laparoscopic approach.

Patient Positioning
The patient is placed in the supine position for both flap harvest and inset. Arms are usually tucked at the patient’s sides. The omentum may be harvested in the lateral position during a left thoracotomy by taking down the diaphragm anteriorly.
GUIDE TO FLAP DISSECTION

Standard Flap
The abdominal cavity is approached through either an open laparotomy incision in the upper midline, or through a laparoscopic technique. Laparoscopic harvest has become increasingly important, and the flap lends itself well to this morbidity-reducing approach. The omentum is evaluated once exposed, assessing its bulk as well the presence of adhesions to unexpected areas of previous intraabdominal inflammation such as the gallbladder, appendix, descending colon (diverticular disease), and pelvis (pelvic inflammatory disease). The distal end of the flap is grasped and elevated to the transverse colon. The transverse colon is inspected, and the transverse mesocolon and its contained middle colic vessels are identified and carefully protected throughout the ensuing dissection.

Flap design (based on right gastroepiploic pedicle)

Fig. 11B-3
The posterior peritoneal reflection of the omentum is carefully dissected off the transverse colon, taking care not to damage the colonic wall. Once free of the colon, the omentum is elevated, exposing the lesser sac beneath and the greater curve of the stomach superiorly. The right and left gastroepiploic vessels are identified, as are the short gastric vessels. At this point the pedicle to be used as the dominant blood supply for the flap must be chosen. If the right vessel is to be used, the left gastroepiploic vessels are ligated immediately distal to their junction with the splenic artery and vein, adjacent to the pancreaticosplenic and gastroepiploic ligaments.
The omentum is mobilized along the greater curve of the stomach, ligating all short gastric contributions and taking care not to constrict any of the gastric wall within the ligatures. If a pedicle flap is planned, mobilization proceeds along the greater curve of the stomach to within 3 cm of the gastric pylorus. If a free flap is required, dissection must proceed to the posterior pylorus to extend the pedicle length.

If the left gastroepiploic vessel is to be used to supply the flap, the vasculature on the right is ligated first, just proximal to the pylorus. The omentum is mobilized off the greater curve of the stomach to 5 to 7 cm from the gastroplenic ligament, taking care not to traumatize the spleen during retraction for exposure.
Extension of Pedicle Length
As mentioned previously, internal dissection within the omentum can lengthen the vascular pedicle considerably. The primary vascular arch is derived from the gastroepiploic vessels. A secondary arcade (Barkow’s arch), is formed by vascular communications along the distal border of the omentum, allowing partial division from the gastroepiploic arcade. The epiploic vessels within the omentum must be clearly visualized with posterior transillumination to determine how the omental sheet may be split longitudinally to maintain viable connections with the source vessels.

FLAP VARIANTS
- Turnover flap
- Segmental flap
- Free flap transfer
- Gastroomental flap
Turnover Flap
After release from the transverse colon, the flap may simply be turned up over the stomach and passed through a mediastinal wound without interrupting the attachments to the stomach. Care must be taken not to kink the stomach, and the width of the flap may predispose the patient to a large paraomental epigastric hernia.

Segmental Flap
The omentum may be split down the center and one half, based on the appropriate gastroepiploic vessel, can be raised to cover smaller defects.

Free Flap Transfer
The flap lends itself well to large defect coverage, although it must be skin grafted if used on a surface wound. Dissection requires skeletonization of the pedicle for anastomosis, and the pedicle can be lengthened by unfurling some of the proximal flap along the vascular arcades contained within the flap. This can obviate the need for vein grafting.

Gastroomental Flap
The omentum can be harvested together with the great curvature of the stomach, based preferably on the left gastroepiploic vessels. This provides an additional cuff of vascularized stomach wall and can be used together to patch an esophageal defect or provide additional coverage to irradiated vessels in the neck. The omentum is then laid over the entire construct to provide a vascularized bed onto which a skin graft can be placed or dead space filled. Another indication for this rarely used flap is in esophageal reconstruction, in which the greater curve of the stomach may be tubed as a partial esophageal reconstruction; the omentum is then wrapped around it as a composite flap. The remaining greater curve of the stomach is closed, creating a smaller gastric pouch while maintaining the continuity of the alimentary tract.
ARC OF ROTATION

A
Arc to chest and mediastinum (right gastroepiploic-based flap)

B
Arc to chest and mediastinum (left gastroepiploic-based flap)

C
Arc to mediastinum (bipedicle turnover flap)

D
Arc to groin and pelvis (right gastroepiploic-based flap)

E
Arc to groin and pelvis (left gastroepiploic-based flap)

F
Arc to posterior trunk

Fig. 11B-6
Before closing the abdomen, it is imperative to repair the defect in the anterior wall of the lesser sac in the donor site to prevent the risk of internal hernia formation or gastric volvulus. This is done with either silk or Vicryl sutures, coapting the greater curvature of the stomach to the transverse colon. Abdominal closure is performed as dictated by the surgical approach to the peritoneal cavity: midline laparotomy incisions are closed as a mass closure with Prolene, whereas laparoscopic incisions are closed in layers with fascial repair.

**FLAP TRANSFER**

The flap is transferred to its recipient site based on the location of the defect. During inset, care should be taken to ensure the flap is not twisted on itself, which can lead to vascular occlusion and flap thrombosis. Any areas of dubious perfusion should be resected back to healthy flap bleeding. Although the flap may be used to fill a defect beneath intact skin, such as in a patient with Rhomberg’s hemifacial atrophy, it is more commonly used as a surface filler and requires immediate skin grafting.

**FLAP INSET**

The omentum is either tunneled over the costal margin onto a chest wall defect, or passed through a small diaphragmatic window into the mediastinum. It can be rotated down into the pelvis, but care should be taken to close off any potential internal hernia sites. The omentum can also be passed through the right paracolic gutter, lateral to the right kidney, allowing its transposition into the back for spinal coverage.
CLINICAL APPLICATIONS
This 20-year-old student sustained full-thickness flame burns to the face and forehead when he lost consciousness in a motor vehicle accident and fire. His face burned for 15 minutes before rescuers were able to free him. He was taken to a major burn unit, where his wounds were debrided and a skin graft was placed, but he was left with an open frontal sinus wound with exposed bone. A free omental flap to the right superficial temporal vessels with skin grafting was planned. The flap was harvested through an open upper midline laparotomy with successful anastomosis to the superficial temporal vessels without vein grafts. He is shown before, during, and 6 months after the procedure, with healed, stable forehead coverage and acceptable contour.

Fig. 11B-8  A, Preoperative view of frontal sinus wound. B, Intraoperative view. C, Free omental flap with the skin graft being sewn in place. D, Frontal view at 6 months postoperatively. E, Lateral profile at 6 months. (Case supplied by GJ.)
This 56-year-old woman with postpolio syndrome developed a large basal cell carcinoma at the vertex of her scalp. The lesion was excised and a skin graft was applied to the galea. Once healed, she received radiation therapy. Five years later she presented with osteoradionecrosis of the skull without any evidence of tumor recurrence. Necrotic bone was present with visible erosion of the inner table of the skull. A wide, full-thickness resection of the skull was planned without bony reconstruction, with coverage by a free omental flap. A latissimus dorsi flap would have been an excellent option, but the patient’s postpolio syndrome precluded using any muscle flaps, and the large surface area of the defect and the need to anastomose to vessels in the neck made the omentum an attractive option. The patient is shown before and 1 year after resection with omental free flap coverage and skin grafting. She was followed for 6 years, during which time her scalp remained healed and stable.

Fig. 11B-9  A, Preoperative view of osteoradionecrosis of the skull. B, Occipital view of the healed, skin-grafted free omental flap to the scalp and dura. C, Lateral view of the scalp with a scar in the neck at the site of pedicle anastomosis to the facial vessels. (Case supplied by G.J.)
This 62-year-old woman had undergone a radical mastectomy 20 years previously, followed by chemotherapy and radiation therapy. She developed progressive osteoradionecrosis of the right chest wall in the region of the costal cartilages. She then experienced a life-threatening hemorrhage from the right internal mammary artery. Radical resection of the chest wall was performed with chest stabilization using Gore-Tex. Soft tissue cover was obtained with a pedicled omental transposition flap and a skin graft. She healed uneventfully, and her chest wall was stable and well healed 3 years after surgery.

Fig. 11B-10  A, Preoperative view of ulcerated right chest wall with exposed costal cartilages. B, Intraoperative defect with chest tubes and Gore-Tex patch in place before omental coverage. C, Postoperative view at 1 year showing healed right chest covered with the skin-grafted omental flap. (Case supplied by G.J.)
This 45-year-old man underwent a four-vessel coronary artery bypass complicated by sternal wound infection. The wound was debrided by the cardiac surgeons, who excised the sternum and splinted the chest wound open with a sternal spreader for 1 week, during which time dressings were applied. By the time he was referred for plastic surgery, the sternal separation had been retracted too much and was too stiff to be closed using conventional pectoral muscle advancement flaps. A pedicled omental flap with a skin graft was performed. The patient is shown intraoperatively, before and after transposition of the omentum flap based on the left gastroepiploic vessels. A skin graft was subsequently applied. The patient healed uneventfully and returned to his home state for long-term follow-up.

Fig. 11B-11  
A, Intraoperative view of the patient’s wide sternal wound after total sternectomy.  
B, Pedicled omental flap in place before skin grafting. (Case supplied by G.J.)
This 55-year-old man with prostate cancer metastatic to the spine developed vertebral collapse requiring instrumentation. He had undergone radiation therapy and developed wound dehiscence. Several unsuccessful attempts, performed elsewhere, had been made to close the wound. The patient was referred for closure. All local options had been exhausted.

**Fig. 11B-12**  
A, The wound is shown at the time of omental flap closure, after debridement.  
B, The omental flap was tunneled through the right paracolic gutter into the spinal wound in preparation for inset and skin grafting.  
C, The omental flap inset before split-thickness skin grafting. The patient healed primarily without any recurrent breakdown until his death 14 months later from widespread metastatic disease. (Case supplied by G.J.)
This 57-year-old man was referred for closure of an infected median sternotomy following coronary artery bypass grafting with bilateral internal mammary artery grafts. A radical sternectomy was necessary to remove all infected bone and cartilage. Given the wide defect dimensions, an omental flap was planned.

**Fig. 11B-13**  
A, The initial draining sternal incision is shown. B, The debrided wound after radical sternectomy. C, The omental flap was elevated in preparation for transposition into the sternal wound. The flap was split along its vascular arcades to allow a portion of the omentum to be packed into the recesses around the great vessels and hila of the lungs. The remaining bulk was placed into the anterior superficial portion of the wound. D, The omental flap inset. E, The flap inset and skin grafted. The patient healed uneventfully and was alive and well with stable wound coverage 2 years later. (Case supplied by G.J.)
Pearls and Pitfalls

- Great care should be taken to ensure that the mesocolon is not accidentally damaged during elevation of the flap from the transverse colon, resulting in colonic ischemia. Similarly, direct sharp penetration of the transverse colon must be avoided at all costs.
- When retracting the costal margins to allow exposure of the left gastroepiploic vessels, the assistant should be aware of the close proximity of the spleen and avoid retractor injuries that can result in immediate or, more seriously, delayed splenic rupture.
- Before the flap is elevated on either of the gastroepiploic vessels, each pedicle in turn should be clamped with a soft vascular clamp to assess pedicle dominance. Although the flap is theoretically viable from either pedicle, there are occasions when the flap is better perfused by one or the other of the two pedicles.
- When ligating the short gastric vessels from the main arcade of the flap, it is important not to include portions of the stomach wall in the ligatures, because this may result in delayed gastric perforation.
- After flap harvest is complete, the greater curve of the stomach should be tacked to the transverse mesocolon to prevent internal herniation or gastric volvulus.
- The omentum can be used as a posterior pull-through flap for spinal wounds when passed through a wound created in the paracolic gutter.

EXPERT COMMENTARY
Glyn Jones

Indications
The omentum is usually large, soft and malleable. It can be used to resurface large surface defects anywhere in the body and is particularly helpful as a volume filler.

Advantages and Limitations
Given its size, the omental flap can cover extremely large surfaces. Its rich blood supply allows it to be unfurled multiple times, enabling it to be extended at least twice its original length to provide deep fill. Its arcadelike blood supply allows it to be split into fingerlike projections, which can be tunneled to fill multiple defects in the face, or may allow it to be wrapped around individual digits in the hand. Its close proximity to the diaphragm allows ready transformation into the mediastinum. It is the flap of choice for extremely large mediastinal defects that are too wide to be closed by the more conventional pectoralis major flaps.

Anatomic Considerations
The omentum is potentially one of the largest surface area flaps in the body and has a rich vascular supply with a reliable, predictable vascular pedicle. As such, it can resurface unusually large defects with a relatively thin tissue mass, but always requires skin grafting when used on surface defects.
Personal Experience and Insights

The omentum is primarily used now for extremely large surface area defects or in areas requiring large but thin coverage. The flap is exceptionally reliable but is very prone to gravitational sagging.

Recommendations

Planning

The omentum should not be used in patients who are emaciated, because the volume can shrink to almost unusable portions. In patients who have had previous abdominal surgery, it should be remembered that the omentum may have been removed as part of the original procedure (such as in a transverse colectomy for cancer or oophorectomy for ovarian cancer). Use in the mediastinum will require substernal or transdiaphragmatic tunneling.

Technique

This flap has traditionally been raised through an open midline laparotomy. In recent years there has been an increasing tendency to harvest the flap laparoscopically in an effort to reduce abdominal morbidity. Before raising the flap completely, it should be transilluminated to evaluate the nature and abundance of the vascular arcades within. It is helpful to occlude the gastroepiploic artery that is not planned to be the pedicle to determine the adequacy of inflow from the selected side. In transposing the flap, great care must be taken not to twist the pedicle.

Postoperative Care

Patients should be treated as in any postlaparotomy case, with restriction of oral fluids and initial bed rest. Thereafter, early ambulation will return bowel function to normal earlier.

Complications: Avoidance and Treatment

The flap’s volume tends to shrink beneath a skin graft. When used in the face or breast, it is particularly prone to gravitational sagging over time. This problem has seen the omentum usurped by fasciocutaneous free flaps or fat injection for the correction of Rhomberg’s hemifacial atrophy. Twisting of the pedicle must be avoided at all costs. In an effort to reduce the bulk of the pedicle passing through the diaphragm into the mediastinum, the pedicle can be skeletonized fairly easily without harm. This reduces the likelihood of subxiphisternal hernia formation.

Take-Away Message

The ability to split the omentum based on Barkow’s secondary arcade allows the use of split omental flaps to cover degloved fingers in devastating hand injuries. The skin grafted fat shrinks back against the digits, providing remarkably good, thin vascularized cover.

Bibliography With Key Annotations

Anatomic/Experimental Studies


The author studied the size and vascular anatomy of the greater omentum in 200 cadavers and 100 laparotomies. He described three methods of lengthening the omentum: detachment of the omentum from the transverse colon, detachment of the greater omentum from the stomach, and division of the omentum according to the network of vascular arcades within the omentum itself. He stated that these lengthening procedures will enable the omentum to reach the skull, midleg, and midforearm in all cases.

The use of the greater omentum as a pedicle flap for revascularization of the brain demonstrated the rapid establishment of vascular connections between the transplanted omentum and the brain tissue.

Clinical Series

General


The authors reported their early experience at the Mayo Clinic in 35 patients in whom the omentum was used for difficult reconstructive problems. Twenty-two patients had radiation necrosis, and 24 patients had documented wound infections. In 26 patients the omentum was the final solution to their difficult reconstructive problems. Complications included partial omental loss in seven patients and secondary debridement and/or skin grafts in 14 patients. One patient required an additional flap for closure, 2 patients had delayed gastric emptying, and there were 3 operative deaths (within 30 days of operation).


In this early review of the use of the omentum for free flap transfer the author described the anatomy and technique of omental microsurgical transplantation. Clinical case examples included coverage of the scalp, extremity reconstruction, and soft tissue augmentation of the face.


The authors described their experience with the omentum as a free flap in 15 patients for reconstruction of difficult wounds. They reported successful reconstruction in 11 of the 15 patients. The location of the defects were as follows: scalp (2), face (2), thigh (2), and lower leg (9). Their rather high failure rate of 27% (4 of 15 patients) was attributed to the use of suboptimal recipient vessels for the microvascular anastomoses. These included vessels with scar tissue, inflammation, and arteriosclerotic changes. The versatility of the omentum for free flap transfer to various anatomic areas is well demonstrated.


The usefulness of various applications of the greater omentum in urology was described, including wrapping the kidney following heminephrectomy, wrapping renal transplants with the greater omentum, and reconstruction of various urinary fistulas.


In this 10-year follow-up review, the author reported his experience with the use of the greater omentum for revascularization of the myocardium. Direct implantation of the internal mammary vessels into the myocardium and the transfer of the greater omentum to the myocardium were described.

Breast Reconstruction


In this very early case report the greater omentum and a custom-made silicone-filled implant were used to reconstruct the breast in a patient who had undergone a radical Halsted-type mastectomy. The omentum was used to cover the custom implant, and the omentum itself was covered with a skin graft.


The authors reported their experience of immediate breast reconstruction using laparoscopically harvested omental flaps (LHOF). During a 44-month period, 44 immediate breast reconstructions with LHOF were performed. Patients were followed for complications and cosmetic results. Forty cases of pedicled LHOF and 4 cases of free LHOF were performed after either nipple-sparing mastectomy
Morbidity included 1 minor vascular injury of the LHOF, 4 wound and graft infections, and 1 epigastric hernia. Cosmetic results were mostly satisfactory, with a soft breast that was natural in appearance. Donor site scars were minimal. However, in 5 patients, the omental flap size was found to be inadequate during the procedure. The authors concluded that although there is a limit of volume, LHOF is an attractive autologous flap that makes a natural soft breast and minimal deformity of the donor site. Long-term atrophy was not addressed in this study.

**Chest Wall Reconstruction**


The authors presented their experience with 12 patients with median sternotomy wound infections who were treated with the greater omentum transposition flap. Seven of their patients had chronically infected wounds, and 5 patients were treated acutely. The patients in the acute group had fewer complications and a shorter hospital stay. The authors concluded that for severe sternal infections, early radical excision of necrotic tissue, omental transposition, and direct closure will reduce morbidity and shorten the hospital stay.


This study reviewed the authors experience with the use of vacuum-assisted closure (VAC) in combination with laparoscopically harvested omental flap and meshed skin graft for treating complex mediastinal wounds resulting from the treatment of breast cancer. Eleven patients underwent chest wall reconstruction with a laparoscopic omentoplasty and VAC treatment of severe chest wall radionecrosis after breast cancer treatment (10) or for locally advanced breast cancer treated first by irradiation (1). Laparoscopic harvesting was uneventful in 10 cases. One patient had a laparoscopic transverse colic resection because of a middle colic artery injury. Mean time of the laparoscopic procedure was 53 minutes (range 35 to 120 minutes). Wound surface area averaged 360 cm² (range 80 to 750 cm²). The mean duration of VAC treatment was 9.3 days (range 6 to 16). Nine patients showed primary wound healing without adverse events. Complications occurred in 3 patients. One developed a pulmonary infection and died after healing during the postoperative course. One presented a partial flap loss, leading to delayed healing after 45 days. One patient with severe radiation damage and a complete brachial plexus paralysis required a shoulder amputation after an extensive necrosis. All but 1 patient survived and resumed their normal daily activities.


This is an early account of the experience with the greater omentum for chest wall reconstruction. Ten patients with extensive defects of the chest wall were included. Eight of these had previously undergone radiation treatment and/or resection for breast cancer. The safety and feasibility of reconstructing these difficult defects with the greater omentum were demonstrated.


The authors presented a case of massive sarcoma resection of the sternum treated with triple plate stabilization and omental wrapping of the plates to provide stable chest wall coverage. The method was suggested as an alternative to complete solid coverage, leaving several options open for future tumor recurrence.


In cardiac surgery, poststernotomy wounds are life-threatening complications, with mortality up to 50%. The authors described two patients who underwent coronary artery bypass grafting and postoperatively...
developed a deep sternal wound infection. Reconstruction was combined with vacuum-assisted closure treatment, laparoscopic mobilization of an omental flap, and split-thickness skin grafts. The use of vacuum-assisted closure treatment and laparoscopic mobilization of great omentum provided a suitable option for treating deep sternal wounds.

**Groin and Perineum Reconstruction**


Thirty-two flaps used for groin, perineum, and abdominal wall reconstruction were reviewed. Three of these were omental flaps used for coverage of the groin and abdominal wall reconstruction, including coverage of synthetic mesh.


Two cases of vaginal evisceration using a combined laparoscopic and vaginal approach employing an omental flap were described. The combined laparoscopic and vaginal approach with omental flap proved effective for repair of a vaginal cuff dehiscence with bowel evisceration. The addition of laparoscopy provides an opportunity for inspection of the small bowel, peritoneal toilet, and mobilization of an omental flap for defect closure.

**Head and Neck Reconstruction**


In this case report the authors used an omental free flap to revascularize rib grafts and skin grafts for facial reconstruction in a patient with an extensive facial defect following a close-range shotgun wound. The use of the greater omentum for reconstruction of such complex defects was demonstrated.


The authors reviewed the literature in light of a repaired pharyngeal defect that was successfully closed after failed pectoralis major flap closure. The high pharyngeal defect in an irradiated bed was closed with a tubed, gastric interpositional segment covered with a skin grafted omental flap.


A technique was reported for transferring a pedicled omentum to the neck to cover the exposed carotid artery following radical neck dissection. The advantages of the omentum include coverage of the exposed carotid artery with well-vascularized tissue that will resist infection and provide a vascular bed for thin neck flaps, especially after irradiation.


The authors reviewed their experience with free tissue transfer in hemifacial atrophy in 12 patients in whom deepithelialized skin flaps and the greater omentum were transferred for soft tissue augmentation of the face. The greater omentum was used in 9 patients and deepithelialized skin flaps in 3 patients. Both gave satisfactory results. The authors stated that the omentum is better suited for more extensive soft tissue defects and deepithelialized skin flap for smaller, limited defects. The long-term sagging of the omentum and the need for resuspension were discussed. They also reported the cases of two patients who had medical-grade liquid silicone injected into the face for amelioration of hemifacial atrophy. In both patients late complications were observed, including chronic inflammation, induration, and sinus tracts, leading the authors to conclude that liquid silicone is not a recommended option in the palliation of Romberg’s disease.

In this report of the first successful microsurgical transplantation of the greater omentum, the authors transferred the greater omentum for coverage of a skull defect following full-thickness resection for a temporoparietal tumor. The omentum was covered with a split-thickness skin graft. The superficial temporal artery and vein were used as the recipient vessels.


The authors described their experience in three patients using the free omental transfer for facial soft tissue augmentation. Their anatomic dissections of the omentum confirmed the five patterns of vascular distribution. They left septa along natural facial contour lines during undermining and preparation of the face for the omental bulk. This compartmentalization was designed to minimize if not totally prevent the sagging that is a problem with the use of the omentum for soft tissue facial augmentation.


The authors presented their experience with the omentum for soft tissue augmentation in seven patients. They described a method for preventing the late sagging of the omentum. Their technique included fixing the omentum to the underlying tissues and overlying skin with multiple sutures and using two vascular pedicles wherever possible. One end of the pedicle was sutured to the facial artery and vein and the other end to the temporal artery and vein, forming a flow-through system with the gastroepiploic vessels.


This first report of microsurgical transplantation of the omentum for correction of hemifacial atrophy involved a young patient who had extensive hemifacial atrophy of the entire left side of her face. The advantages of the omentum include the volume of tissue available, the size of the vascular pedicle, and the fact that “many flaps” of omentum could be developed for placement within the eyelids and other facial regions.

Lower Extremity Coverage

A technique was described whereby an elongated omental pedicle flap was transferred into the lower extremity. The authors included a study of the vascular anatomy of the omentum and flap-lengthening techniques. They reported their experience in 24 patients with peripheral vascular disease who had not benefited from other surgical methods. They reported some success and radiographically demonstrated an increase in vascularity in extremities following the omental transfer.

Flap Modifications

An omental-lengthening technique based on the arterial anatomy of the omentum was described and the vascular arcades of the greater omentum were evaluated. The left gastroepiploic vessels are divided high up on the greater curvature of the stomach and the gastroepiploic arcade is mobilized all the way to the pylorus. Then, depending on the arterial supply within the omentum itself, the arcades are isolated and divided to lengthen the omentum, basing it on the right gastroepiploic vessels and the anastomotic channels within the omentum. With these lengthening procedures, the authors claimed that the greater omentum can easily reach the scalp or even the distal lower extremity.

The authors presented their experience with the greater omentum as a transposition flap for coverage of wounds of the chest, as a modified extended flap for coverage of the neck, and as a pedicle flap for staged reconstruction of upper extremity wounds. Free flap transfer for coverage of scalp and skull wounds as well as lower extremity defects was demonstrated.


The authors transferred the omentum as a free flap for coverage of an extensive radionecrotic ulcer of the thigh with an exposed femur. Since the gastroepiploic vessels were sutured into an irradiated set of femoral vessels, there was considerable concern over the success of the vascular anastomosis and the viability of the omentum. Therefore they delayed the resection of the defect for 48 hours to ensure complete survival of the omentum before resecting the defect.


The omentum together with a portion of the greater curvature of the stomach was used for reconstruction of a soft tissue defect of the neck and the cervical esophagus. The gastric portion was tubed and used for reconstruction of the esophagus and the omentum draped over for soft tissue coverage. The authors reported on four patients, all of whom had preoperative radiation treatment and extensive neck wounds. All were successfully reconstructed.


In this first report of successful endoscopic harvest of the greater omentum, the authors successfully transferred the omentum as a free flap for coverage of an extensive lower extremity wound. Through a small subcostal incision and laparoscopic ports, the authors successfully harvested the greater omentum using endoscopic techniques.


A soft tissue defect of the right side of the face was successfully reconstructed following basal cell carcinoma resection. An omental-lengthening technique was used to transfer the omentum to the face without microsurgical transplantation. The authors used several small transverse incisions to tunnel the greater omentum from the xiphoid across the chest and neck to the defect on the right side. The reconstruction in their patient yielded satisfactory results.

Complications

A single omental free flap was used to augment both sides of the face of a 23-year-old man. The reconstruction was initially successful, but at 8 weeks postoperatively the patient presented with pain and edema of the face. His face was explored, and a diagnosis of foreign body reaction was documented by electron microscopy. The patient was successfully managed with a course of steroids. The cause of this reaction was not established.


A 61-year-old woman with a recurrence of breast cancer underwent chest wall resection and reconstruction with Marlex mesh and an omental flap. Two weeks after discharge from the hospital, she was readmitted with acute abdominal pain. At operation a volvulus of the cecum was found. The cecum was released and a cecostomy was performed. Two days later, another laparotomy was performed because of peritonitis as a result of cecal rupture. The patient eventually died from complications related to the cecal rupture. The authors thought that the cecal volvulus may have resulted from the release of the omental attachments to the ascending colon, which predisposed the patient to the fatal cecal volvulus.
Chapter 12

Thigh

Until recently, thigh-based flaps have been relegated to the domain of locoregional applications. They have been invaluable for covering decubitus ulcers, groin wounds, orthopedic wounds of the hip, and vascular exposures. Although the gracilis flap saw utility early as a free flap for lower extremity coverage, it has evolved into the most widely used source of free innervated muscle for facial reanimation and functional muscle transfers to the upper extremity. With the advent of the TUG flap, it has widened its applicability to breast reconstruction. In addition, the ALT flap has become one of the major workhorse perforator flaps in reconstruction, particularly for head and neck reconstruction. As a remote donor site with expendable muscles and a large surface area for flap creation, the thigh has become a favorite among microsurgeons.

Anterolateral Thigh (ALT) and Anteromedial Thigh (AMT) Flaps
Saphenous and Medial Condylar Flaps
Gracilis and TUG/TMG Flaps
Sartorius Flap
Biceps Femoris (Hamstring) Flap
Tensor Fascia Lata (TFL) Flap
Vastus Lateralis Flap
Rectus Femoris Flap
**ANATOMIC LANDMARKS**

<table>
<thead>
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<th>Landmarks</th>
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<td>This myocutaneous perforator flap or septocutaneous flap provides tissue from the anterolateral surface of the thigh from a point 10 cm inferior to the anterior superior iliac spine to a point 7 cm superior to the patella. The medial flap border is the midpoint of the rectus femoris muscle; the lateral border is the mid-lateral thigh.</td>
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| Size |
| 25 × 35 cm (with skin grafting of the donor site); a variable amount of vastus lateralis muscle may also be carried with the flap. |

| Composition |
| Myocutaneous, septocutaneous. |

| Dominant Pedicle |
| Septocutaneous and myocutaneous branches of the descending branch of the lateral circumflex femoral artery. |

| Nerve Supply |
| Sensory: Lateral femoral cutaneous nerve (L2-L3). |
Section 12A

THIGH
Anterolateral Thigh (ALT) and Anteromedial Thigh (AMT) Flaps

CLINICAL APPLICATIONS

Regional Use
- Groin
- Lower abdomen
- Thigh
- Knee

Distant Use
- Head and neck reconstruction
- Upper extremity reconstruction
- Lower extremity reconstruction

Specialized Use
- Esophageal reconstruction
ANATOMY OF THE ANTEROLATERAL THIGH (ALT) AND ANTEROMEDIAL THIGH (AMT) FLAPS

**Fig. 12A-1**  A, The vascular anatomy of the thigh relevant to the ALT and AMT flaps. B, Anatomy of the lateral circumflex femoral artery and its branches and thigh vasculature.

**Dominant pedicle:** Septocutaneous and myocutaneous branches of descending branch of lateral circumflex femoral artery (LCFA)
ANATOMY

Landmarks
The flap occupies the anterolateral portion of the thigh from approximately 10 cm below the anterior superior iliac spine (ASIS) to within 7 cm superior of the patella. The medial margin of the flap territory is at the midpoint of the rectus femoris muscle. Laterally the anterolateral thigh (ALT) flap extends to the midlateral thigh.

Composition
Myocutaneous, septocutaneous.

Size
25 × 35 cm (with skin grafting of the donor site). Primary closure is usually obtainable when the flap width is 10 cm or less. A variable amount of vastus lateralis muscle may also be carried with the flap.

Arterial Anatomy

Dominant Pedicle
Septocutaneous and myocutaneous branches of the descending branch of the lateral circumflex femoral artery

Regional Source
Profunda femoral artery.

Length
12 cm.

Diameter
2 mm.

Location
After its takeoff from the lateral circumflex femoral artery (LCFA), the descending branch enters the deep fascia through the medial aspect of the vastus lateralis. Most perforators to the skin perforate the vastus lateralis muscle, so dissection must either include some muscle or dissect the vessels through the muscle. Less commonly the perforators are purely septocutaneous, and this is more common in the proximal third of the thigh.

Venous Anatomy

Venae comitantes accompany the descending branch of the lateral circumflex femoral artery. The average pedicle length is 12 cm, and the diameter at the takeoff of the descending lateral circumflex femoral vein is 2 to 3 mm.
Nerve Supply

Sensory Lateral femoral cutaneous nerve (L2–L3). It emerges from under the inguinal ligament 1 cm medial to the ASIS, where it divides into its anterior and posterior branches. The anterior branch runs underneath the fascia lata for approximately 10 cm before piercing it and supplying the skin of the anterolateral thigh. The posterior branch variably pierces the fascia lata more proximally and laterally and supplies the lateral thigh.

Fig. 12A-1 C, Sensory map of the lateral femoral cutaneous nerve and its branches. D, Sensory innervation of the anterior thigh.
VASCULAR ANATOMY OF THE ANTEROLATERAL THIGH FLAP

Fig. 12A-2  A, Cadaveric dissection of the ALT flap showing a proximal septocutaneous and more distal myocutaneous perforator, which required intramuscular dissection. B, Closeup of the origin of the lateral femoral cutaneous branch showing the two perforators combined proximally.
**FLAP HARVEST**

**Design and Markings**

A line is drawn from the ASIS to the superior lateral border of the patella. A circle with a radius of 3 cm is drawn at the midway point, which should localize one of the perforators of the ALT flap. Doppler examination is used to identify this point and any other vessels that perforate its lower, outer quadrants. Although flaps as large as 25 by 35 cm have been harvested on a single perforator, a skin graft is required for donor site closure. Flap widths of 9 to 10 cm allow their donor sites to be closed primarily.

![Diagram of ALT flap harvest](image)

**Fig. 12A-3**  
A, With the patient in the supine position, the central axis of the flap is indicated by a line drawn from the anterior superior iliac spine to the superior lateral border of the patella. The major fasciocutaneous perforators supplying the flap can be located at the midpoint of this line, within the lower, outer quadrant (shaded area) of a circle drawn with a radius of 3 cm.  
B, The medial flap border corresponds to the central axis of the rectus femoris muscle, denoted by the line drawn from the anterior superior iliac spine to the superior aspect of the patella. The lateral flap border extends to the midlateral thigh. The lateral circumflex femoral artery arises from the lateral side of the profunda femoris artery. It then passes laterally deep to the femoral nerve branches and the sartorius and rectus femoris muscles. It divides into ascending, transverse, and descending branches (and an innominate branch). Note the lateral femoral cutaneous nerve entering the thigh by passing under or through the lateral end of the inguinal ligament. The anterior branch can be employed to innervate the flap.
Patient Positioning
Patient positioning is supine with circumferential prep of the donor leg.

GUIDE TO FLAP DISSECTION
A medial incision is made first down to and through thigh fascia, which will expose the rectus femoris muscle. Dissection then proceeds in a subfascial plane laterally toward the septum between the rectus femoris and the vastus lateralis muscles. Retraction of the rectus femoris muscle medially will help to expose the vessels as they traverse the septum. The descending branch of the lateral circumflex femoral artery should be visualized within the septum, or more commonly, perforating through the medialmost portions of the vastus lateralis muscle. When a septocutaneous vessel is present and dominant, the dissection is simplified. If vascularization of the skin is from a perforator that runs through the vastus lateralis, an intramuscular dissection must be performed. Careful dissection will reveal the course of the vessel. Once it emerges from the deep surface of the muscle, the remainder of the dissection is similar to the septocutaneous case. If the surgeon does not want to dissect the perforators through the muscle, some vastus lateralis muscle can be taken to incorporate these perforators. In this case, the incorporated muscle acts only as a carrier of the perforators. This limits the length of the pedicle for the flap for the distance of this intramuscular course. Put another way, performing intramuscular dissection of the perforator will lengthen the pedicle.

Fig. 12A-4

Elevation of the anterior portion of the flap

Dissection of the vascular pedicle

Flap completion

Rectus femoris muscle
Vastus intermedius muscle
Rectus femoris muscle
Descending branch of LCFA

Rectus femoris muscle
Vastus lateralis muscle
Descending branch of LCFA

Rectus femoris muscle
Vastus lateralis muscle
Vastus intermedius muscle
FLAP VARIANTS

- Thin flap (suprafascial dissection)
- Anteromedial thigh flap
- Reverse anterolateral thigh flap

Thin Flap

When a thin flap is required for coverage or significant folding of the flap is required, thinning of the ALT flap should be considered. First, an incision is made similar to that used in a subfascial dissection; however, the depth is to the level of the fascia without dividing it. Dissection continues above fascia, heading laterally approaching the area of the localized Doppler signal. The suprafascial dissection involves more bleeding; care must be taken to minimize any staining of the surrounding tissues to facilitate dissection and assist the surgeon to visualize the perforating vessels. Cutaneous nerves that may be present can be left in situ on the fascia. Once the vessel is identified, the lateral incision is made and a suprafascial dissection heading medially is performed until the same vessel is now seen from the opposite side. The fascia is incised, and the vessel is then dissected in retrograde fashion through muscle or in the septum until the desired pedicle length and vessel caliber are seen.

Fig. 12A-5  A, Thigh flap elevated in a suprafascial plane on a single skin vessel. Although donor site morbidity is limited by leaving the fascia, the visibility of landmarks that could facilitate pedicle dissection is more limited.

While the flap is still attached to the leg but is isolated on its pedicle, further thinning of the flap can be performed; a circle of at least 2 cm radius is preserved around the perforating vessel. This area is not thinned to maintain perfusion around the perforators. The remainder of the flap may be directly thinned first by removing any deep fat that appears to have bigger fat lobules than the more superficial fat, which has more of the smaller, round fat lobules. A thin fascia may be found between these two fatty levels to aid dissection. Defatting before division of the pedicle ensures viability of the flap to be transferred.

Fig. 12A-5  B, The blood supply of the cutaneous perforator with the subdermal plexus. C, Flap thinning with the subdermal plexus intact.
Anteromedial Thigh Flap
When no significant Doppler signal can be found in the lateral septum, the medial border of the rectus femoris muscle should also be investigated, because some patients will have a system that is more medially dominant. The anteromedial thigh perforator, based on the innominate branch of the lateral circumflex femoral descending artery, exits medial to the rectus femoris muscle and supplies branches to the vastus medialis and sartorius muscles and a skin territory that is more anteriorly based. If this is discovered during the planning phase, the skin design should be moved more medially, centered over the rectus femoris muscle. Incision of the medial edge of the flap is performed first and a subfascial dissection is performed until the medial perforator is found. This can then be dissected down to the descending lateral circumflex femoral system.

Fig. 12A-6  A, Anatomy of the anteromedial thigh flap. B, The innominate branch arises directly from the lateral circumflex femoral artery. It courses posteromedially to the rectus femoris muscle on the vastus medialis muscle, giving off multiple muscle branches and myocutaneous branches to the vastus medialis and sartorius muscles. A dominant septocutaneous branch usually emerges at the juncture of the rectus femoris, sartorius, and vastus medialis muscles in the middle of the thigh. The cutaneous paddle is supplied by the anterior femoral cutaneous nerve.
When more bulk is needed for the flap or when the best vascularity is required, the rectus femoris muscle can be included with the flap. A larger flap design can incorporate the ALT perforators on the lateral side of the rectus femoris muscle and the AMT perforators on the medial side. Both perforators originate from the same descending lateral circumflex femoral arterial system.

Reverse Anterolateral Thigh Flap

The descending lateral femoral system runs the length of the thigh and maintains good caliber distally such that a reverse flow flap is possible. For difficult knee wounds, this flap can be considered. The skin design is more distally based. Dissection proceeds in similar fashion with medial incision first through the fascia to the rectus femoris muscle. Once the vessel is exposed and is thought to be of adequate size, the pedicle can be ligated superiorly and a rotational flap created that will extend inferiorly.
**ARC OF ROTATION**

**Anterolateral Thigh Flap**

Depending on how distal the skin paddle is planned, the ALT flap can easily reach to the groin and lower abdomen for soft tissue coverage. Large anterior thigh–based flaps have been described for abdominal wall reconstruction with flaps extending to just above the knee reaching the costal margin.

![Diagram of Flap Elevation](image1)

![Diagram of Arc to Inferior Abdomen and Ipsilateral Groin](image2)

![Diagram of Arc to Posterior Trunk and Ischium](image3)

**Fig. 12A-8** Proximally based standard flap.

**Reverse Flap**

Depending on the location of the skin paddle, the reverse flap should easily reach to defects around the knee or popliteal fossa.

![Diagram of Arc of Rotation for Reverse ALT Flap](image4)

**Fig. 12A-9** Arc of rotation for the reverse ALT flap. The pivot point for the reverse flap is shown; this can be used to approximate the arc inferiorly.
FLAP TRANSFER
When the ALT flap is used regionally, it is often transposed through a subcutaneous tunnel. Care must be taken to make sure the tunnel is not restrictive and does not compromise blood supply in any way. When used as a free tissue transfer, kinking or compression of the vessels is less of an issue.

FLAP INSET
Care is taken to secure the flap in place through either the fascia or muscle included with the flap. Care must be taken to ensure a tension-free inset. As a free flap, often the flap is tacked in place to ensure proper positioning of the microsurgery and prevention of redundancy of such a long pedicle.

DONOR SITE CLOSURE
All Flap Variants
When the skin paddle is limited to 9 or 10 cm in width, primary closure should be obtainable. When primary closure is not obtainable, a skin graft may be required for closure of the donor site.

CLINICAL APPLICATIONS
This 60-year-old woman had a history of radiation-induced angiosarcoma of the right chest. She initially underwent reconstruction with a VRAM flap and received a radiation boost for her recurrence.

Fig. 12A-10  A, The patient developed this open wound as a result of her second course of irradiation. Biopsies were negative for recurrent angiosarcoma, and reconstruction was required. Advancement of the VRAM was felt to be too problematic after the radiation treatment and the nature of the local tissues. An ALT flap was planned as a free flap to the internal mammary system. B, The flap design after Doppler identification of the perforators and transposition of the templated defect. C, After debridement and resurfacing with an ALT free flap. The donor site was closed primarily. D, The flap healed uneventfully, seen here at 5 months postoperatively. (Case supplied by MRZ.)
This 47-year-old man had a recurrent squamous cell carcinoma of the skin invading the orbit. He required a wide excision with orbital exenteration, leaving a complex, irradiated wound. The ALT is the flap of choice for such wounds, because it supplies ample skin for resurfacing and well-vascularized muscle in the vastus lateralis for fill of the irradiated defect.

Fig. 12A-11  A, The operative defect with exposed dura and maxillary sinus and a large skin defect.  B, Flap elevated on the descending lateral circumflex femoral pedicle. The blood supply to the skin was based on intramuscular perforators.  C, Prior to revascularization, the flap was partially inset with the muscle used for fill of the irradiated dead space.  D, After revascularization, the skin paddle and muscle are healthy and ready for inset. The pedicle vessels easily reached to the neck for anastomosis with the facial artery and vein.  E, Final inset. He healed uneventfully. (Case supplied by MRZ.)
This 55-year-old man had a maxillary squamous cell sarcoma requiring radical excision, including the maxilla and soft tissues of the cheek. The orbital contents were spared, but the lower eyelid had outer lamella removed and lacked bony support.

Fig. 12A-12  A, The defect is seen and a planned Tripier flap is marked on the upper lid for reconstruction of the lower lid. B, The Tripier flap is transposed and inset and a porous polyethylene implant was used to replace the orbital floor. An ALT flap was planned for soft tissue replacement. C, The design of the ALT flap was positioned over the area of maximal fluorescence on ICG laser angiography. D, The ALT inset. The included fascia was secured to the remaining lateral zygomatic arch with Mitek suture anchors. The donor site was closed primarily. E, AP view and F, oblique view at 1 month. He underwent postoperative irradiation, which the flap tolerated well. He remains tumor free at 7 years. (Case supplied by MRZ.)
This 65-year-old man had a history of pharyngeal squamous cell carcinoma treated with resection, pectoralis major flap, and postoperative radiation. He had partial necrosis of his reconstruction, wound dehiscence, and a salivary fistula. He was referred for free flap reconstruction.

**Fig. 12A-13**  
A, Defect after debridement of necrotic skin and pectoralis flap. Only a posterior strip of cervical esophagus remained. The anterior neck skin was removed, and a remnant of unusable pectoralis major muscle remained. B, Planned two-paddle ALT flap, one for esophageal reconstruction, one for resurfacing of the neck. C, Flap after elevation, with good viability of both skin paddles. Perforators coursed through the vastus lateralis muscle and some was included with the flap. D, Undersurface of flap. The donor site required skin grafting for closure. E, Insetting of the flap for esophageal reconstruction. F, After inset of the larger flap to resurface the anterior neck. Because of the added bulk of the included vastus lateralis muscle, primary closure was not attempted, and the exposed muscle was skin grafted. (Case supplied by MRZ.)
Hypopharyngeal cancer reconstruction presents a number of challenges that favor using an ALT flap. Following extensive resection of the pharynx, larynx, and esophagus, and a bilateral node dissection, significant dead space remains. Although the radial forearm flap, for example, can be easily fashioned into a skin tube, it may lack sufficient tissue bulk to restore volume in the neck. Furthermore, the amount of skin may be inadequate to close the neck wound, because patients have commonly received radiation as an organ-preserving therapy. It is generally an advantage to have an ample supply of tissue available in this setting, making the ALT flap a preferred treatment. An ALT flap was used to reconstruct this pharyngoesophageal defect.

Fig. 12A-14  A, Hypopharyngeal cancer specimen including larynx, pharynx, and cervical esophagus.  B, In this case, the axis of the skin tube was oriented perpendicular to the length of the thigh.  C, The skin paddle was tubed using a two-layer closure of skin and fascia.  D, Flap inset is shown with adequate volume restoration.  E, An esophagram demonstrated rapid, unobstructed passage through the skin tube. (Case courtesy Fu-Chen Wei, MD.)
This 50-year-old woman had undergone multiple abdominal surgeries and had a history of sepsis and recurrent fistulas. The lateral circumflex femoral vessels are versatile for providing vascularized skin, fascia, muscle, and/or bone alone or can be used in combination to solve a wide variety of reconstructive challenges.

Fig. 12A-15  A, The patient had a large defect of the left upper quadrant with infected acellular dermal matrix. B, The wound was debrided, and an extended ALT myocutaneous flap was raised, supplied by the descending and medial (innominate) branches of the lateral circumflex femoral artery. Thigh fascia was to be used to close the abdominal wall defect. C, The abdominal wall defect was closed. The thigh donor site was closed with a perforator-based V-Y flap (arrow) from the posterolateral thigh circulation. (Case courtesy Lawrence J. Gottlieb, MD.)
This 58-year-old man developed a postradiation sarcoma 1 year after reconstruction of his mandible with an osteoseptocutaneous fibula flap for osteoradionecrosis.

**Fig. 12A-16**  
A, The dashed line outlines the cutaneous portion of the radiation sarcoma. The arrow marks the fibula skin paddle. B, The resection defect included a small mucosal defect, 5 cm of neomandible (fibula), and skin. C, A split iliac crest chimera flap with 5 cm of split lateral iliac crest (white arrow) supplied by the ascending branch (red arrow) of the lateral circumflex femoral vessels; the flap incorporated a portion of vastus lateralis muscle to close dead space and the mucosal lining defect supplied by the descending branch (blue arrow) of the lateral circumflex femoral vessels and a large skin paddle supplied by a septocutaneous branch of the lateral circumflex femoral vessels. D, The flap was inset. The split lateral iliac crest (arrow) supplied by the ascending branch of the lateral circumflex femoral vessels is shown after insetting. The vastus lateralis muscle was used to close dead space and the mucosal lining defect (curved arrow depicts where the muscle flap was placed). Microvascular anastomoses were performed to the peroneal artery and vein (the old fibula pedicle), and then the skin was inset. E, Immediate result after insetting and closure of the skin paddle. (Case courtesy Lawrence J. Gottlieb, MD.)
This 72-year-old man had recurrent right maxillary cancer after initial treatment with radiation. A split lateral iliac crest flap was planned.

**Fig. 12A-17**  
A, The patient is seen preoperatively. B, He had an ulcerated tumor of the right maxilla. C, Resected specimen. D, Thigh donor site demonstrating lateral iliac crest (white arrow), marked for the proposed line to split. E, Flap with split lateral iliac crest (arrow) attached to the tensor fascia lata, supplied by the ascending branch (red arrow) of lateral circumflex femoral vessels. The skin paddle (to be used as a monitor and to take tension off the neck skin closure) was supplied by a septocutaneous vessel (blue arrow). F, Flap inset. The split lateral iliac crest (white arrow) was osteotomized to fit the exact size and shape of the defect. The attached tensor fascia lata (red arrow) was used to reconstruct the palate, which was left raw to remucosalize. G, Skin closure. The green nasal trumpet was left to support the nasal floor lining, which remucosalizes on its own. Note the skin-monitoring paddle on the lower right. (Case courtesy Lawrence J. Gottlieb, MD.)
This 57-year-old man sustained head trauma from a mishap with fireworks.

**Fig. 12A-18**  A, The scalp injury is seen, with exposed, fractured cranium. B, The wound was debrided. C and D, A muscle-sparing adipose fascial ALT flap was harvested. E, The flap was inset. F, The patient is seen at 1-year follow-up. A split-thickness skin graft was used to cover the adipose fascial flap. (Case courtesy Lawrence J. Gottlieb, MD.)
This 76-year-old man presented with a recurrent squamous cell carcinoma in the larynx following previous radiation therapy and bilateral neck dissection.

Fig. 12A-19  A, A total laryngopharyngectomy was performed, with resection of neck skin. B, A two–skin island ALT flap was designed with a flap width of 9.5 cm to create a neoesophagus with a diameter of 3 cm. C, The proximal end of the flap was oriented to reconstruct the nasopharynx–base of tongue region. The flap was divided between the two cutaneous perforators. D, A Montgomery salivary bypass tube was placed in the lumen of the tubed flap and to the distal esophagus. E, The second skin island, based on the perforator marked C was externalized to resurface the neck. (Case courtesy Peirong Yu, MD.)
This 61-year-old man underwent a composite maxillectomy for a recurrent maxillary cancer.

Fig. 12A-20  A, The resulting defect involved the facial skin, orbit, anterior craniobase with dural repair, the right hemimaxilla including the palate, and the nasal sidewall. B, A multiisland ALT flap was designed for this three-dimensional reconstruction. C, The skin island based on the perforator marked C was used to reconstruct the nasal sidewall. D, The main flap based on perforator A was used for facial resurfacing. E, The proximal segment of the flap was used to reconstruct the palate after deepithelializing a strip of the flap skin. (Case courtesy Peirong Yu, MD.)
This 62-year-old woman presented with a fractured left mandible that resulted from osteoradionecrosis after treatment for her base-of-tongue cancer.

**Fig. 12A-21**  
A. The patient had been wearing an external fixator for more than a year, with a fistula.  
B. The fractured left mandible, including the condyle, was removed.  
C. Because of her peripheral vascular disease, a fibular flap was not performed. Instead, a two–skin island ALT flap with a segment of the vastus lateralis muscle was used to reconstruct this through-and-through mandibulectomy defect.  
D and E. At 6-month follow-up, the flap was well healed and the patient had good mouth opening. She was able to tolerate a regular diet. (Case courtesy Peirong Yu, MD.)
This 48-year-old woman presented with recurrent tongue cancer.

**Fig. 12A-22**  A, The patient underwent a total glossectomy. B and C, An ALT flap was harvested, with a segment of the vastus lateralis muscle and its motor nerve and the lateral femoral cutaneous sensory nerve for both motor and sensory reinnervation. D, The motor nerve was anastomosed to the hypoglossal nerve, and the sensory nerve to the lingual nerve. E, The patient had excellent sensory reinnervation, although motor nerve recovery was minimal. (Case courtesy Peirong Yu, MD.)
This 36-year-old man with tracheomalacia presented for reconstruction.

**Fig. 12A-23**  
A, Defect after resection of involved cartilage. B, Tubing of the ALT around a tracheostomy tube for proper sizing. C, The flap is inset with the endotracheal tube transferred into position. Microvascular anastomoses are completed, and the skin is ready for closure without tension. (Case courtesy Peirong Yu, MD.)

**Pearls and Pitfalls**

- When perforating vessels appear too small for safe intramuscular dissection, a patch of vastus lateralis muscle should be taken with the flap. In patients who are obese, avoid overthinning of the flap initially, as it is harder to visualize blood vessels and maintain a viable flap. A secondary flap thinning is acceptable.
- A skin-grafted donor site may not be aesthetically acceptable for the patient, and a V-Y advancement of neighboring thigh flaps or use of tissue expansion for removal of the skin graft can be considered.
- The caliber of the descending lateral circumflex femoral system is such that the ALT flap is an excellent (flow-through) flap, whereby a second free flap can be attached in series.
- The descending lateral circumflex femoral artery and vein make an excellent A-V graft in situations where an A-V loop is being considered. Which parts of the vessels are harvested for this A-V graft will depend on the diameters of the vessels being anastomosed.
- Overzealous closure of the donor site to prevent the use of a skin graft may result in muscle ischemia, leg swelling, and compartment syndrome with subsequent nerve injury. One should have a low threshold to place a skin graft when the closure appears tight.
- It is helpful to carry more than one perforator to the skin; this allows improved flow and helps maintain proper orientation of the vessels during transfer and inset, decreasing the likelihood of twisting or kinking.
EXPERT COMMENTARY
Lawrence J. Gottlieb

Indications
The anterior lateral thigh (ALT) flap was first described as a septocutaneous flap based on the descending branch of the lateral circumflex femoral artery (LCFA), and subsequently this ALT terminology was broadened to include almost any flap based on the lateral circumflex femoral system. Although initially popularized as a workhorse for head and neck reconstruction, it has subsequently become a popular pedicle flap with a reach from the epigastrium to the knee, and as a free flap for extremity and chest wall reconstruction.

Advantages and Limitations
The anterior lateral thigh is a storehouse of “spare parts” tissue that may be used throughout the body. Skin, fat, fascia, muscle, and up to 10 cm of bone can be transferred independently or in combination based off of the LCFA vascular system. The main advantages of the LCFA-based flaps are their versatility and ability to be harvested in the supine position usually simultaneously with tumor extirpation or wound preparation at distant sites. The main limitations of LCFA–based flaps include body habitus (obesity) and color mismatch when the skin of the thigh is transferred to the head and neck. The donor site can create an unsightly scar. At best, it is a linear scar on the anterior lateral thigh; at worst, it is a depressed split–thickness skin graft scar.

Anatomic Considerations
Most straightforward ALT flaps are based on the descending branch of the LCFA, as originally described. Anatomic variability or complex reconstructive needs may require the use of tissue supplied by the transverse branch, innominate (medial descending) branch, the ascending branch, or a combination of these. Invariably, there is a septocutaneous vessel located approximately 17 to 18 cm from the anterior superior iliac spine (ASIS) in an average-sized adult. Occasionally, this vessel is very small or covered by a small slip of vastus lateralis muscle. Frequently, this perforator originates from the transverse branch of the LCFA rather than the descending branch. It emerges just distal to the tensor fascia lata (TFL) muscle, and the skin overlying the TFL can be captured with this vessel. Anterior medial skin may be included with the ALT flap, to increase surface area or as an additional skin paddle, by including the innominate (medial descending) branch. This vessel usually originates from the proximal descending branch of the LCFA system, frequently having a common origin with one of the major arteries supplying the rectus femoris muscle. The innominate vessels are usually septocutaneous and emerge into the subcutaneous fat just distal to where the sartorius crosses the rectus femoris muscle.
By including the ascending branch of the LCFA system, up to 10 cm of the iliac crest can be included with this flap. This vessel runs just beneath the anterior edge of the TFL. Adding vascularized corticocancellous bone to flaps based on the LCFA system provides tremendous versatility for head and neck and extremity reconstruction.

As one includes more branches of the LCFA vascular system (either as a compound or chimeric flap), it frequently becomes necessary to dissect the pedicle all the way to the profundus femoral artery and vein. In doing so, anatomic variations become more evident. Only 60% to 70% of legs have the “classic” three branches of the LCF artery and vein come off of the LCF artery and vein. In some, the artery (of any one of the branches) has an aberrant takeoff, and in others, the vein drains differently from what one would expect. When including multiple branches of the LCFA system or even with multiple perforators off the same branch, the surgeon must consider the branches of the femoral nerve, which will frequently go between the branches or perforators, requiring division of either the nerve or vessel to elevate the flap.

Continued
Part II  Regional Flaps: Anatomy and Basic Techniques

Personal Experience and Insights

It is rare that I use the ALT free flap based on a single perforator or septocutaneous vessel to transfer a single skin paddle. More frequently, I use multiple perforators to transfer a large paddle of skin or a flap with multiple paddles of tissue as a chimera. Recognizing the possibility of anatomic variations, I advocate a freestyle approach, usually beginning with a midline incision in the proximal thigh to define the vessels available, tissue types required, and length of pedicle required before committing to a particular skin paddle. Because I usually harvest more then one perforator, I invariably have to deal with crossing nerves. Occasionally a small paddle of skin or muscle with its attached vessels can be passed under the nerve branch. When this is not possible, I usually cut the nerve close to the muscle that it is innervating, pull it through, and then repair it after the flap is elevated. If a large branch or multiple branches of the nerve are “in the way,” I cut the blood vessels to reanastomose them later.

Recommendations

Planning

The first consideration in planning is to determine what tissue types (skin, fat, fascia, muscle, bone) are needed to accomplish the reconstructive goals. In designing chimeric flaps, one needs to be able to separate or deconstruct angiosomes (and venosomes) by their source vessels or perforators so that each tissue component can be placed with special independence, but still linked to the common source vessel (the pedicle). The approximate size of each component, the anticipated blood supply to these tissues, and the three-dimensional details and sequence of insetting needs to be carefully thought out. Additional relevant factors in planning include the pedicle length needed to reach the anticipated recipient vessels in a free flap or to reach the defect if transferred as a pedicle flap. The length of the ascending branch, transverse branch, medial innominate branch, and first septocutaneous branch tends to be approximately 10 cm. The descending branch with perforators through the muscle tends to be 13 to 15 cm long.

I rarely do preoperative imaging studies and find preoperative Doppler examination to be unreliable. With the significant number of anatomic variations of the LCFA vascular system, it is imperative to have a lifeboat or backup plan if the vessels are not as anticipated. This may include looking for the medial innominate vessels (as described earlier) to supply a

Fig. 12A-26  Branches of the femoral nerve (yellow vessel loops) going over the transverse branch, then under the first septocutaneous vessel. In such complex relationships, care is taken to preserve the nerve. The pedicle can be passed through after division, just before microscopic anastomosis.
skin paddle if there are none suitable laterally or to perfuse a second skin paddle. Sometimes
the transverse or superior (ascending) branches going through the TFL muscle are the only
significant vessels supplying lateral thigh skin from the LCF system. Alternatively, if two
paddles of skin are required and only one perforator is found, two paddles can be fashioned
with an intervening deepithelialized area, or muscle (with or without a skin graft) can be
used as a substitute for one of the skin paddles.

Technique
I use a freestyle approach in harvesting LCF-based flaps with slightly different markings
and an initial incision that is more medial and proximal than that described in the chapter.
In addition to the standard marking of a vertical line from the ASIS to the lateral edge of
the patella, an additional vertical line is drawn from the ASIS to the midline of the patella.
Two horizontal lines are then drawn 10 cm and 17.5 cm below the ASIS. The proximal
horizontal line marks the location of the LCF vessels and the second horizontal line marks
the distal end of the tensor fascia lata, where a septocutaneous vessel is usually found. A
10 cm vertical skin incision, centered over the proximal horizontal line is made on the medial
vertical line. This incision is used primarily for orientation and for defining the anatomy
and tissue planes. It is carried down through the fascia and the rectus femoris is identified
and retracted medially revealing the underlying septum under which the LCF vessels are
found. In contradistinction to freestyle elevation of a simple perforator flap, complex chimera
flaps are best dissected from the pedicle to the various tissue components of the chimera flap
using a combination of retrograde and anterograde dissection of the perforators.

Fig. 12A-27  A, Markings for an LCF chimera
flap. The red markings indicate the anticipated
location of vessels; the black line with dots in-
dicates the initial incision. B, Extension of the
initial incision to the second horizontal line. The
arrow depicts the septocutaneous vessels usu-
ally found going to the second horizontal line,
approximately 17.5 cm from the ASIS. C, After
freestyle dissection of the vessels supplying the
complex chimera flap.
Postoperative Care
If lateral thigh fascia or muscle is used in the flap, the knee is immobilized in extension for 4 to 6 weeks postoperatively. Isometric exercises are started 1 week after surgery, and aggressive physical therapy to strengthen the quadriceps muscles is initiated 6 weeks postoperatively.

Complications: Avoidance and Treatment
When multiple branches of the LCF system are included in the flap, care must be taken to not twist or kink the perforators, branches, or pedicle. Marking one surface of the vessels with a marking pen in situ will help the surgeon recognize a twist sooner rather than later.

Any disruption of the fascia lata or iliotibial tract can lead to knee instability, particularly in extension. This can be avoided by using a knee immobilizer, as described earlier.

Although preoperative imaging is unnecessary for most patients, it should be considered in patients with peripheral vascular disease, because critical collateral blood flow may be using the profunda system to perfuse the leg.

Take-Away Messages
By melding the principles and concepts of angiosomes and the freestyle technique of perforator flap dissection, a variety of complex flaps with multiple tissue components can be custom designed and tailored into a chimeric flap for almost any reconstructive need. However, in a patient who is morbidly obese and requires a long piece of bone, or in the occasional patient who has a paucity of vessels, the usefulness of this flap may be limited.

EXPERT COMMENTARY
Peirong Yu

Indications
I have used the ALT flap as a free flap for reconstruction for a variety of defects in the head and neck, chest wall, and extremities. It can also be used as a pedicled flap for scrotal and perineal reconstruction, contralateral groin reconstruction, and reconstruction of pelvic exenteration defects when the vertical rectus abdominis myocutaneous flap is unavailable or inadequate.

Anatomic Considerations

Vascular Anatomy
Although the descending branch of the LCFA supplies the ALT flap in most cases, occasionally the only perforators to the flap may arise from the transverse branch; this which has occurred in 2% of my cases. This perforator usually travels within the vastus lateralis muscle for its entire length, making dissection more tedious. The surgeon needs to be aware of this variation.

Perforator Anatomy
In early years, the perforator anatomy of the ALT flap had a reputation for being inconsistent. Although many early publications described the perforator as being located within a 3 cm radius of the midpoint of the line connecting the ASIS and the supralateral corner of the patella (AP line), careful study of the perforator anatomy has demonstrated that in most cases there is more than one useful perforator (usually one to three), and their surface
locations follow a pattern (the ABC system). The perforator that is most consistently present is located near the midpoint of the AP line, perforator B. Approximately 5 cm more proximal and distal to that, a second and third perforator may be found (perforators A and C). The average distance (longitudinally) measured from the ASIS to perforators A, B, and C is 18.4 ± 2.2 cm, 23.5 ± 2.0 cm, and 28.6 ± 2.3 cm, respectively (data from 244 ALT free flaps). On the horizontal axis, the cutaneous perforators are located an average of 1.4 cm lateral to the AP line. Forty-nine percent of patients have two perforators, 26% have a single perforator (most commonly perforator B), and 25% have three perforators.

In general, the proximal perforators are larger than distal ones (A > B > C). The proximal perforators are also more likely to be septocutaneous, whereas the distal ones are more likely to be myocutaneous (46% of perforator A, 19% of perforator B, and 12% of perforator C are septocutaneous). However, the proximal thigh is thicker than the distal thigh. The thickness at the level of perforator A is 20% thicker than that at perforator B, which is 18% thicker than that at perforator C. Therefore, when a thinner flap is needed, one should look for more distal perforators, which are smaller and more likely myocutaneous.

**Fig. 12A-28** Surface locations of the cutaneous perforators of the ALT flap. Perforator B is usually located near the midpoint of the line connecting the ASIS and the supralateral corner of the patella (the AP line), but 1.4 cm lateral to the line. Perforators A and C are located 5 cm proximal and distal to perforator B, respectively.

**Recommendations**

**Planning**

Leg positioning is extremely important, especially in obese patients. It is critical to position the lower extremity neutral with the knee and foot pointing to the ceiling. Circumferential skin preparation is not necessary. The most prominent point of the ASIS and the supralateral corner of the patella are marked, and a straight line is drawn to connect these two landmarks. This line is called the AP line. The presumed location of perforator B is marked 1.5 cm lateral to and near the midpoint of the AP line. Next, the presumed locations of perforators A and C are marked 5 cm proximal and distal to the presumed perforator B, respectively. The estimated flap dimension is outlined, centering on perforator B. One must bear in mind that the flap design may need to be recentered based on the actual perforator locations.

Most surgeons use a handheld Doppler device to detect the perforators. However, handheld Doppler examination can be inaccurate and misleading; therefore it should be used with caution. None of the current imaging studies is accurate in identifying the perforators. My experience suggests that the ABC system is the most accurate for locating perforators.

*Continued*
**Technique**

For an average-sized flap (6 to 10 cm wide), the medial incision usually falls along the anterior midline of the thigh or 1.5 to 2.0 cm medial to the AP line. The medial incision, approximately 15 cm long and spanning all three presumed perforators, is made first down to the fascia over the rectus femoris muscle (see Fig. 12A-28). Subfascial dissection is easier for less-experienced surgeons, because the “septum” between the vastus lateralis and rectus femoris muscles can be easily identified in the subfascial plane. The fascia is retracted laterally with three Allis clamps, with each one positioned at a perforator location. Once the septum is identified, dissection must proceed more carefully. Since perforator B is most consistent, it should be sought first. With the marked locations of the perforators and the positions of the three Allis clamps, one should know exactly where to look for them. Once the perforators are found, the descending branch is exposed. Intramuscular dissection is carried out, if necessary, from distal (where the perforator exits the muscle) to proximal through the muscle. All the flap dissections can be performed through the medial incision only. It is important not to island the flap before identifying and dissecting out the perforators. The lateral incision may need to be modified based on the exact perforator locations and the final dimensions of the defect. If a long vascular pedicle is not needed, the pedicle can be divided below the rectus femoris branch that supplies the rectus femoris muscle. An additional 2 cm of pedicle length can be obtained proximal to the rectus femoris branch.

**What to Do When No ALT Perforators Are Found**

In my early experience of 250 ALT flaps, 4.3% of thighs had no perforators in the ALT flap territory. The contralateral thigh or an entirely different flap had to be chosen, resulting in wasted time, additional incisions, and the potential for increased operative morbidity. In addition, 26% had only one perforator. If a double skin island flap is needed, one may wonder what next step is best. In our recent experience with the anteromedial thigh (AMT) flap, the best option seems to be exploring the AMT flap perforators to either include or convert to an AMT flap.

![Fig. 12A-29](image)  
*Fig. 12A-29* The AMT flap is a mirror image of the ALT flap. When the ALT flap perforators are unfavorable, the AMT flap should be explored through the same incision.

Although the blood supply to the AMT flap has been inconsistent in the literature, our 100 AMT flap explorations suggest that it is the perforators from the rectus femoris branch off the descending branch that descends medially along the medial border of the rectus femoris muscle. This branch was also called the *innominate branch* in the past, but it is very clear that it is the same branch that supplies the rectus femoris muscle and is always seen when
dividing the ALT flap pedicle, the descending branch. Therefore, by taking the descending branch proximal to the rectus femoris branch, one can potentially create a multi-island ALT-AMT flap.

In our series, perforators from the rectus femoris branch to supply the AMT flap were present in only 51% of cases. However, when there were no ALT perforators, all but one patient had AMT perforators. When there was only one ALT perforator, the chances of having an AMT perforator were 75%. The locations of the AMT perforators along the Y axis are very similar to the locations of the ALT perforators, with the B perforator near the midpoint of the AP line and A and C perforators 5 cm proximal and distal to the B perforator, respectively. On the X axis, the AMT perforators are located, on average, 3.2 cm medial to the AP line, corresponding to the intermuscular space between the rectus femoris and sartorius–vastus medialis muscles.

Therefore, when the ALT perforator anatomy is unfavorable, one should simply explore the AMT perforators using the same incision. Since the AMT flap lies on the opposite side of the AP line to the ALT flap, the AMT flap can be designed as a mirror image of the ALT flap.

References

Continued

**Bibliography With Key Annotations**


*In the past two decades, the ALT flap has emerged as one of the most popular reconstructive options for multiple body sites. This article summarized the anatomy, planning, flap harvest, donor morbidity, and clinical applications of the ALT flap. The flap has proved to be extremely useful in skin resurfacing and even functional reconstruction in traumatic wounds. The authors proposed an algorithm to facilitate a clear, problem-based approach for the use of this versatile reconstructive option.*


*Free tissue transfer has revolutionized skull-base surgery by expanding the ability to perform cranial base resection and by improving the quality of reconstruction. The ALT flap has recently come into use in head and neck reconstruction. Its role in craniofacial and midface reconstruction has not been specifically defined. The authors reviewed 18 patients who were treated over a 5-year period. The authors noted that the flap's advantage in skull-base reconstruction is its reliable blood supply, which can provide adequate dural cover and protection of the brain. Its size and moderate thickness are suitable for reconstruction of scalp and calvarial defects. The abundance of reliably vascularized fat in the flap may be an advantage in long-term maintenance of the volume of the flap in midface reconstruction. Similar to other soft tissue flaps, additional skeletal reconstruction may still be required to achieve an optimal functional and aesthetic result.*


*Primary closure of the donor site after flap harvest is key to achieving a satisfactory result. This article focused on the width of the harvested ALT flap to permit primary closure of the donor site. The flap width-to-thigh circumference ratio is a reliable parameter for preoperative planning of primary closure of the ALT flap donor site. The authors concluded that primary closure can be achieved if the flap width-to-thigh circumference ratio is less than 16%, taking body mass index and age into consideration.*


*The ALT perforator flap from the ipsilateral thigh based on the distalmost perforator can provide skin and soft tissue coverage around the knee with a satisfactory clinical outcome. The operative procedure is easy and reliable. This flap is an option for soft tissue reconstruction around the knee.*


*Simultaneous reconstruction of two separate defects by two free flaps is time consuming and often requires two donor sites. The anterior and lateral aspect of the thigh is an ideal donor site for free tissue harvest without incurring significant morbidity. The authors described their recently developed technique, which allows harvesting two independent fasciocutaneous free flaps from the same descending branch of the lateral circumflex femoral vessel as a new clinical application of the versatile ALT flap.*

Muscles used for patellar and peripatellar soft tissue construction, which include the vastus medialis, vastus lateralis, gastrocnemius, and sartorius muscles, are often clinically inadequate for reconstruction of the patellar and peripatellar regions. Split-thickness skin grafts are also inadequate for supporting superficial patellar tendons and resisting perpetual shear stress. The authors reported their experience with distally based anteromedial thigh fasciocutaneous island flaps for patellar soft tissue reconstruction in seven patients. The authors concluded that this flap is a useful and viable option for patellar soft tissue reconstruction because of its versatile vascular pedicle, pliable deep fascia, adequate retrograde perfusion, and the possibility of direct closure of the donor site when no losses of the medial thigh are expected.


The authors reported their experience using a free ALT flap to cover buccal mucosal defects after buccal cancer resection. Nine patients underwent primary surgical treatment between June 2005 and September 2006. An ALT flap was used to repair the buccal defect immediately after tumor resection. Oral function, including mouth-opening width, oral intake, and teeth cleaning, were compared preoperatively and postoperatively. No difference was observed in the mouth-opening width between that measured preoperatively and 3 months postoperatively. The oral intake and teeth cleaning also remained unchanged 3 months postoperatively. The authors concluded that repair of a buccal mucosa defect with a free anterior lateral thigh flap is a good alternative for selected patients.


Because the skin of the anteromedial thigh region typically is thin, pliable, and hairless, it can be a preferred flap based on the requirements of the recipient site. This article presented a cadaveric study in which 204 perforators were dissected in 16 lower extremities, providing useful knowledge about localizations and number of ALT perforators. The authors concluded that septocutaneous perforators of the anteromedial aspect of the thigh are as important as the myocutaneous perforators, and all are adequate to perform an anteromedial thigh flap.


Immediate flap reconstruction for partial vaginal resection is often performed with resection of colorectal, gynecologic, and urologic malignancies. Surgical and functional outcomes have not been well described. This article highlighted the factors associated with improved outcomes in patients undergoing immediate flap reconstruction for partial vaginal resection. The authors reviewed 72 consecutive partial vaginal resections with immediate flap reconstruction performed between 2000 and 2009. Mean follow-up was 32 months (range 1 to 93 months). Complications were higher in patients who received preoperative radiation therapy than in those who did not (66% versus 25%) and who had posterior defects rather than anterior defects (66% versus 30%). Patients with postoperative complications had higher preoperative radiation doses. Of 24 patients with available postoperative sexual function data, 68% reported successful penile-vaginal intercourse. Immediate flap reconstruction for partial vaginal resection has a high incidence of minor complications. Preoperative radiotherapy is associated with increased complications. Most patients able to have penile-vaginal intercourse preoperatively also could postoperatively. The authors concluded that immediate flap reconstruction for partial vaginal resection should be considered for patients undergoing pelvic oncologic resection; however, counseling on relevant risks and functional outcomes is vital.


During ALT flap harvest, inadequate perforators may necessitate modification of the flap design, exploration of the contralateral thigh, or additional flap harvest. CT angiography (CTA) may facilitate perforator mapping and optimize flap design. The authors reported on 16 consecutive CTA–
mapped ALT flaps for head and neck reconstruction. Perforator location, origin, caliber, and course were compared between CTA and intraoperative findings. The relationship of patient characteristics, imaging studies, and intraoperative factors to flap design and surgical outcomes was analyzed. CTA identified larger perforators better than smaller ones and proximal perforators better than distal ones. It accurately predicted the location and origin of visible perforators and less accurately predicted the size and course of visible perforators.


The ascending branch of the lateral circumflex artery may be of value as an alternative recipient vessel in the free flap transfer to the hip region. The author reviewed the anatomy of the ascending branch of the lateral circumflex femoral vessels with regard to size, location, and length and on the basis of previous anatomic and clinical studies in the literature. The ascending vessels were used in the free flap reconstruction of the hip wounds in two case examples. The ascending vessels followed an oblique course behind the rectus femoris muscle to reach the hilus of the tensor fascia lata muscle laterally and superiorly. The vessels were located 7 to 12 cm from the anterior superior iliac spine in the interval between the rectus femoris and tensor fascia latae muscles. The external diameter of the artery varied between 2 and 3 mm, accompanied by two venae comitantes measuring 1.8 to 2.5 mm. The ascending branch has a predictable location, a consistent anatomy, and an adequate caliber, and its surgical exposure is relatively easy.


The authors reported the outcomes of patients undergoing reconstruction after resection of skull-base tumors with the ALT free flap. Thirty-four consecutive patients with cancers involving the skull base underwent reconstruction with the ALT free flap between 2005 and 2008. The ALT free flap was successfully used to reconstruct 2, 5, and 17 anterior, lateral, and posterior skull-base defects, respectively. In addition, 6 and 4 combined anterior-lateral and lateral-posterior defects, respectively, were reconstructed. The overall complication rate was 29%. There were no flap losses. Nerve grafts (6) and fascial slings (14) for facial reanimation were performed using the lateral femoral cutaneous nerve and fascia lata from the same donor site as the ALT free flap. By harvesting the flap and grafts simultaneous with the resection, an average of 3 hours per case was saved. The authors concluded that the ALT free flap is a versatile, reliable flap that should be considered a first-line option for skull-base reconstruction. Operative time is minimized by performing a simultaneous two-team approach to resection and reconstruction, and by harvesting nerve, vein, and fascial grafts from the same donor site as the flap.


The authors described an updated and comprehensive algorithm for skull-base reconstruction based on data from a 10-year period. Reconstructive outcomes were analyzed from 250 patients undergoing skull-base reconstruction from 2000 to 2009. Based on the largest series of skull-base reconstructions to date, the authors recommended pedicled flaps for limited defects because of minimal donor site morbidity and shorter operative times and hospital stays. For extensive defects and cases involving prior surgery, irradiation, or chemotherapy, free flaps are preferred. The authors concluded that facial nerve repair should be attempted whenever feasible, even when in the presence of preoperative weakness, anticipated postoperative irradiation, or advanced age.


The goal of sole reconstruction should be functional and aesthetic. These goals can be achieved by providing the sole with a durable and comfortable weight-bearing surface, adequate contour, protective sensation, and solid anchoring to deep tissue to resist shearing. Various flaps such as fasciocutaneous, myocutaneous, or split skin grafted muscle flaps have been reported for reconstruction of the weight-
bearing foot. The authors reported on 69 patients treated for soft tissue defects in the plantar areas with ALT perforator free flaps. Sensory nerve coaptation was performed in 17 cases. The follow-up period ranged from 4 to 38 months, with a mean of 14.7 months. Most patients regained protective sensation by 12 months regardless of nerve coaptation, but earlier sensory recovery was noted in patients who underwent reconstruction with sensate flaps. The authors suggested that the ALT perforator flap is a reliable option in sole reconstruction, resulting in an acceptable functional and aesthetic outcome.


This article highlighted new flow-through perforator flaps with a large, short vascular pedicle because of their clinical significance and a high success rate for reconstruction of the lower legs. Of 13 consecutive cases, the authors described 2 cases of successful transfer of a short-pedicle anterolateral or anteromedial thigh flow-through flap for coverage of soft tissue defects in the legs. This new flap has a thin fatty layer and a small fascial component and is vascularized with a perforator originating from a short segment of the descending branch of the lateral circumflex femoral system. The advantages of this flap are as follows: flow-through anastomosis ensures a high success rate for free flaps and preserves the recipient arterial flow; there is no need for dissecting throughout the lateral circumflex femoral system as the pedicle vessel; minimal time is required for flap elevation; there is minimal donor site morbidity; and the flap is obtained from a thin portion of the thigh. Even in obese patients, thinning of the flap with primary defatting is possible, and the donor scar is concealed. The authors stated that this flap is suitable for coverage of defects in legs where a single arterial flow remains and that it is also suitable for chronic lower leg ulcers, osteomyelitis, and plantar coverage.


Chronic recurrent ischial sores are an important cause of morbidity in paraplegics and geriatric patients. Compared to sacral and trochanteric ulcers, ischial sores are the most difficult to treat, with a low success rate following conservative therapy and a high recurrence rate after surgical treatment. This article reviewed the use of the pedicled anterolateral thigh (pALT) flap for reconstruction of a chronic ischial sore. The free ALT flap has an established role in reconstruction in the head and neck and extremities. As a pedicled flap, it has been used in the primary reconstruction of the perineum, groin, anterior abdominal wall, thigh and ischium. The authors presented the first reported case of a paraplegic man with a recurrent ischial sore treated successfully with an island pALT flap inset via a lateral subcutaneous approach. The authors discussed the indications and its role as a simple and reliable secondary reconstructive option in the treatment of recurrent ischial ulcers after first-line locoregional surgical options have been exhausted.


The ALT flap is commonly used for reconstruction of various soft tissue defects. The authors presented their approach to one-stage reconstruction of composite soft tissue defects using an ALT flap with a vascularized fascia lata; 973 patients underwent ALT flap reconstruction for various soft tissue defects over 10 years. Various types of complicated defects in 36 patients were reconstructed with a composite ALT flap combined with vascularized fascia lata. Functional outcomes of donor sites were measured with a dynamometer. The overall flap survival rate was 97%. Patients achieved satisfactory results without major postoperative complications. The study revealed that vascularized fascia may mimic a fascial sheath but lacks the muscle-synchronized excursion properties. Apart from a mild deficiency in quadriceps femoris muscle contraction in the donor thighs, no difficulties in daily ambulation were reported by the patients. The authors concluded that ALT flap with vascularized fascia lata provides a reliable fascial component for single-stage reconstruction of complex soft tissue defects.

The authors evaluated their experience with consecutive cases of the pedicled ALT flap in complex abdominal and pelvic reconstruction. A retrospective review of medical records and photographic archives was performed on 28 proximally pedicled ALT flaps in 27 patients. The authors identified the arcs of rotation achieved, the types of defects reconstructed, points of surgical technique that enhanced their results, and some pitfalls of this flap. Useful points of surgical technique identified included suprafascial flap harvesting, extended harvesting of fascia, use of fascia to protect the pedicle, harvesting as a composite flap with the vastus lateralis, synergistic use with a sartorius “switch,” complete flap deepithelialization to fill dead space, and simple conversion to a free flap when pedicle length is inadequate. Pitfalls identified included the increased risk of pedicle avulsion in the morbidly obese, the risk of atherosclerotic plaque embolization in an atheromatous pedicle, and the potential inadequacy of thigh fascia for reconstituting abdominal wall integrity.


This was the first reported case of single-flap total penile reconstruction using a pedicled ALT flap. Although both the ALT flap and the radial forearm free flap can create functional phallus, the distinct advantage of the pedicled ALT flap reconstruction is that there is no need for microsurgery, and no ischemic time. The ALT flap also produces a more aesthetic reconstruction; it provides bulk that is less prone to atrophy, with a better color match and a donor site scar that is easier to conceal. The pedicled ALT flap is the authors' first choice for penile reconstruction.


Microsurgical free flap surgery has progressed from simply providing wound coverage to restoring a high level of function. The authors used 44 free flaps to restore functional and structural defects in the lower limbs. The versatility of the LCFA system allowed use of the anterolateral thigh, vastus lateralis, tensor fascia lata, rectus femoris, and iliac crest. Combinations of tissues from this system were employed to restore defects in the patellar tendon, Achilles tendon, extensor hallucis tendon, anterior compartment with or without lateral compartment muscle, anterior compartment muscle and segmental tibial bone, and composite calcaneus. The free flap success rate was 97.7%. Four reconstructions were performed, with one subsequent failure. Eight patients (18.2%) developed wound infections, of which two required secondary amputations, resulting in a limb salvage rate of 95.4%. The authors concluded that the LCFA system provides a predictable and versatile surplus of tissue necessary to restore functional and structural integrity of the posttraumatic lower extremity in a single stage.


This article reviewed the subjective and the objective functional and aesthetic follow-up results of the recipient and donor sites after reconstruction of extensive facial defects with the ALT flap. The ALT flap was used to reconstruct large facial skin defects after malignant tumor resection in 23 patients. All patients had a standardized interview, physical examination, and clinical photographs. Fasciocutaneous ALT flaps were used in 15 patients and myocutaneous flaps were used in eight patients with exposed dura, open sinuses, or orbital defects. An extra free osteocutaneous fibula flap was necessary to reconstruct the affected mandible in 10 patients. The donor site was skin grafted in 18 patients. The flap survival rate was 96%. At follow-up, color mismatch (71%) and flap bulkiness (50%) were encountered most often. Four of five patients with speech problems received an additional free osteocutaneous fibula flap. Three flap contractures were seen in the neck region. A contour defect of
the upper leg was encountered in five patients. Sensory disturbances of the upper leg were observed in 12 patients. Cold intolerance occurred three times after skin grafting. No significant impairment was found in range of motion and muscle strength of the donor leg. The authors stated that careful patient selection may further improve aesthetic outcome of the ALT flap. They concluded that the versatility in design and composition of the ALT flap and the low donor site morbidity and satisfactory recipient site outcome make it a valuable option in reconstruction of external skin defects in the head and neck region.


The ALT perforator flap is increasingly being used for trauma and reconstructive surgical cases. With the thinned flap design, greater survivability and a decrease in donor site morbidity are observed. This article reviewed an anatomic study performed to determine pedicle number, location, and diameter; accompanying veins; vascular territory; and where surgical incisions can be made safely during thinning, as opposed to the danger zone. Thirteen ALT perforator flaps were harvested from seven adult cadavers. The largest perforator arteries were cannulated, and flaps were thinned to a thickness of 6 to 8 mm, with a 2.5 cm radius from the perforator retained. Vascular territories were quantified before and after thinning by nonradiographic and radiographic methods. A series of dyes were injected: red dye for skin (photography) followed by Omnipaque for the whole flap (radiography) before thinning, and blue dye for skin (photography) and lead oxide for the whole flap (radiography) after thinning. Pedicle locations were determined by ratios of anatomic landmarks. Danger zone measurements were derived at specific thicknesses using lateral radiographs of each flap. Four respective vascular territory maps were drawn showing surgical territories using percentile confidence intervals (98th and 90th) and averages. From the skin at thicknesses of 4, 6, and 8 mm, the 98th percentile danger zones were 33 to 37 mm (proximal to distal), 30 to 35 mm, and 27 to 31 mm from the pedicle in the vertical axis, respectively; in the horizontal axis, they were 30 to 34 mm (medial to lateral), 28 to 31 mm, and 25 to 29 mm. These data define ALT perforator flap pedicle location, number, and diameter before harvesting, surgical danger zones during thinning, and vascular territories after thinning. The authors' guidelines provide surgeons with anatomic vascular territory maps to design and harvest specific flaps for optimal results.


Complex cranioorbitomaxillary reconstructions are highly demanding for the plastic surgeon; moreover, suboptimal reconstruction can limit excisional operations because of intracranial complications or disfiguring results. The anterolateral thigh flap can provide an acceptable one-stage reconstruction with minimal intracranial complications. A flap design consisting of two skin islands for nasal lining and palatal closure, a portion of vastus lateralis for dead space collapse and bulk, and a suspension of the whole reconstruction with vascularized fascia can provide a satisfactory reconstruction with minimal complications and donor site morbidity.


The ALT flap can be reliably extended to include adjacent vascular territories. The vascular basis of this phenomenon is poorly understood. This article focused on the three- and four-dimensional arterial and venous anatomy of the extended anterolateral thigh flap and reviews the results of a clinical series of extended anterolateral thigh flaps. Fifteen anterior hemithigh specimens were harvested from fresh cadavers. Four-dimensional CT angiography was used to investigate the arterial and venous anatomy and pattern of perfusion. Injection of perforators within the lateral circumflex femoral vascular territory, and those of the common femoral and superficial femoral arteries, was performed to investigate the vascular connections within the extended anterolateral thigh flap. Static three-dimensional imaging and
latex dissections were also performed to confirm the results. A clinical series of 12 consecutive patients was reviewed in which extended ALT flaps were used for posttrauma or postoncologic reconstruction. The authors highlighted the vascular basis and clinical safety of the extended ALT flap, which can be harvested if the linking vessels between adjacent vascular territories in the anterior thigh are preserved. The authors show that the extended flap is reliably perfused by a single dominant perforator.


The authors reported their series of five patients treated with the AMT flap for defects in the head and neck region and lower extremity. They consistently found the pedicle as an emerging septocutaneous perforator at a point at which the medial border of the rectus femoris muscle is crossed by the sartorius muscle. In all five patients, the AMT flap provided stable coverage with no flap loss. They concluded that the anteromedial thigh flap offers all the advantages of fasciocutaneous flaps. Therefore this flap is a useful alternative for defects requiring coverages of thin to moderate skin thickness.


This article reviewed the authors’ experience over 5 years with reconstructions of hypopharyngeal defects using ALT flaps. Fifty-five ALT flaps were harvested for reconstruction of hypopharyngeal defects after tumor ablation in 54 patients. Patient age ranged from 38 to 77 years (average 54 years). In 24 cases, free flaps were used for reconstruction of circumferential defects; in 28 cases, they were used to reconstruct partial defects; and in 3 cases, they were used to reconstruct circumferential and skin defects. Total flap loss occurred in 1 patient and partial flap loss occurred in 3 patients. Strictures occurred in three patients and fistulas occurred in 10. In one case, arterial occlusion was noticed postoperatively. The arterial anastomosis was revised and the flap was salvaged. In another case, venous occlusion was noted. The vein was reanastomosed with a vein graft and the flap was salvaged. Postoperatively, seven patients tolerated a regular diet. The donor site was skin grafted in five cases, closed with reverse ALT in one case and with retrograde V-Y advancement flap in one case, and closed primarily in the rest. There were no donor site complications. The authors concluded that reconstruction of the hypopharynx with the ALT flap offers versatility in the coverage of large and complex defects and is associated with minimal donor site morbidity.


The rectus abdominis may be unavailable or insufficient to reconstruct large pelvic exenteration defects. This article reviewed the authors’ experience with the pedicled anterolateral thigh–vastus lateralis muscle flap for such reconstructions. Eighteen patients with pelvic exenteration underwent reconstruction with this flap. When the perineal defect could be closed primarily, the vastus lateralis muscle was tunneled over the inguinal ligament into the pelvis (inguinal route). For concomitant perineal-vaginal reconstruction, the ALT–vastus lateralis muscle was tunneled over the medial thigh to the defect (perineal route). All 18 patients received preoperative chemoradiation. Nine patients received intraoperative pelvic brachytherapy. After pelvic exenteration, a colostomy was created in all patients, and a urestomy with ileal conduit was created in 8 patients. The inguinal route was used in 6 patients and the perineal route was used in 10 patients. In the remaining 2 patients, the anterolateral thigh–vastus lateralis muscle from one thigh was delivered through the perineal route and the contralateral vastus lateralis flap was delivered through the inguinal route. Postoperative complications included five small perineal wound dehiscences that healed spontaneously, one flap failure caused by pedicle tension in an obese patient with a short thigh, an enterocutaneous fistula, and an ileal conduit leak that healed spontaneously. No hernias occurred.

The authors presented their experience using free thin ALT flaps combined with cervicoplasty in a series of seven patients who underwent reconstruction for previous burn injury. The authors used a suprafascial dissection technique to provide a thin flap to improve cervical contour. Neck contractures had resulted from flame burns in six patients and from a chemical burn in one patient. The size of flaps ranged from 11 by 5 cm to 26 by 8 cm. The average operative time was 6 hours, and the average hospital stay was 10 days. All flaps survived, with one flap sustaining partial marginal loss. The donor site was closed primarily in five cases and with a split-thickness skin graft in two cases. At follow-up, the functional improvement included a mean increase in extension of 30 degrees, in rotation 18 degrees, and in lateral flexion 12.5 degrees. The average cervicomandibular angle was improved by 25 degrees. The authors concluded that the use of free thin ALT flaps combined with cervicoplasty in a one-stage reconstruction with a thin, pliable flap achieves good cervical contour with low donor site morbidity.


This article highlighted the perforator patterns and vascular anatomy of the ALT flap. In the authors’ investigation, 21 of 100 thighs had no anteromedial thigh perforators. For the remaining thighs, there were two sources of perforators: the rectus femoris branch of the descending branch of the lateral circumflex femoral artery, and the superficial femoral artery. Perforators from the latter were short and small and thus less useful. AMT flaps based on rectus femoris branch perforators shared the same vascular pedicle as the ALT flap and were thus clinically useful. However, these rectus femoris branch perforators were present in only 51% of the patients. Their surface locations followed a similar pattern as the ALT flap, with the majority of perforators near the midpoint, but an average of 3.2 cm medial to a line connecting the anterior superior iliac spine and the superolateral patella. Forty-three thighs had a single rectus femoris branch perforator and eight had two perforators; 66% were septocutaneous, and the rest traversed a thin layer of the rectus femoris muscle. The authors concluded that it is best to plan the anteromedial thigh flap to complement the ALT rather than to be the primary flap.


Vulvar defects after tumor extirpation always require immediate reconstruction. Transferring a skin flap from a distant region may be required for large defects. The authors reviewed their experience with the ALT flap for vulvar reconstruction. Eleven patients with vulvar carcinoma underwent resection and immediate reconstruction with the ALT flap. Based on defect type and local soft tissue quality, four types of ALT flap reconstructions were performed: unilateral ALT flap, ipsilateral ALT flap combined with contralateral advancement flap or local flap, fenestrated ALT flap, and split ALT flap. Postoperative complications were recorded and clinical outcomes were evaluated. Partial flap necrosis occurred in one patient with a fenestrated ALT flap for bilateral reconstruction. One wound dehiscence occurred in the contralateral local flap. Two patients had prolonged serous drainage. Mean follow-up was 8 months. One patient developed stricture of the urethral meatus and another had regional metastasis. The authors concluded that with careful design, the ALT flap may provide reliable and durable soft tissue coverage for various vulvar defects with good outcomes and minimal donor site morbidity.
ANATOMIC LANDMARKS

**Landmarks**
The area of the medial knee, extending from the medial border of the patella to the medial border of the popliteal fossa. The flap can extend 10 cm above the knee to approximately 20 cm below it.

**Size**
8 × 25 cm.

**Composition**
Fasciocutaneous, type A.

**Dominant Pedicle**
Saphenous artery.

**Nerve Supply**
*Sensory:* Anterior femoral cutaneous nerve, saphenous nerve.
**Section 12B**

**THIGH**

*Saphenous and Medial Condylar Flaps*

**CLINICAL APPLICATIONS**

*Regional Use*
- Thigh
- Knee
- Popliteal fossa

*Distant Use*
- Head and neck
- Upper extremity
- Lower extremity
ANATOMY OF THE SAPHEOUS AND MEDIAL CONDYULAR FLAPS

Fig. 12B-1

Dominant pedicle: Saphenous artery
ANATOMY

Landmarks  Flap occupies the area medial to the knee, running from the medial border of the patella to the medial border of the popliteal fossa. The flap can extend 10 cm above the knee and 20 cm below the knee.

Composition  Fasciocutaneous.

Size  $8 \times 25$ cm.

Arterial Anatomy

Dominant Pedicle  Saphenous artery

Regional Source  Descending genicular artery from the superficial femoral artery.

Length  5 to 15 cm.

Diameter  1.5 to 2 mm.

Location  The descending genicular artery arises from the medial side of the superficial femoral artery just proximal to where the superficial femoral artery passes into the adductor canal. The proximal portion of the genicular artery lies deep to the roof of the canal. One of its major branches is the saphenous artery. The saphenous artery runs in a distal, superficial direction, and within 2 cm of its origin it pierces the adductor canal roof and courses within a loose fascial space deep to the sartorius muscle. The artery runs distally in this plane for up to 15 cm. It then passes into the medial aspect of the leg near the insertion of the sartorius muscle. The cutaneous perforators supply the proximal flap and branch along the course of the artery under the sartorius muscle; these branches are anterior and posterior to the sartorius muscle and vary greatly in size and number. Fifty percent of the time, the anterior branches are the major blood supply to the skin territory immediately anterior to the sartorius muscle. In the knee area, the saphenous artery and the branches of the descending geniculate artery have a rich collateralization with the superior and inferior genicular arteries. These are the basis of the reverse flow saphenous flap.

Venous Anatomy

Paired venae comitantes accompany the descending genicular artery; these combine and drain into the superficial femoral vein. The diameter at this point is 2 to 2.5 mm. The flap is also drained by the greater saphenous vein that runs superficially within this territory, 1 to 2 cm posterior to the artery. The vein in this region is quite thick, measuring 3 to 4 mm.

Nerve Supply

Sensory  Two nerves supply sensation to different regions of the flap. The medial femoral cutaneous nerve is a branch of the femoral nerve that pierces the deep fascia of the thigh in the lower third of the leg and follows the medial border of the sartorius muscle in a plane superficial to the fascia. Its anterior branch provides sensation to the superior portion of the flap above the knee; its posterior branch continues distally beneath the deep fascia, piercing it at the level of the knee and supplying a cutaneous distribution that is more posterior.

The saphenous nerve is a cutaneous branch of the femoral nerve that follows the saphenous artery in the subsartorial space and pierces the deep fascia with the saphenous artery proximal to the sartorius insertion. The saphenous nerve then follows the greater saphenous vein through the leg, remaining posterior to the vein. This nerve supplies sensation to the medial knee, as well as to the distal anterior medial leg and the medial border of the foot.
Vascular Anatomy of the Saphenous and Medial Condylar Flaps

Flap elevated with proximal pedicle dissected

Flap after harvest

Radiographic dye injection study of flap

Fig. 12B-2

Dominant pedicle: Saphenous artery branch of descending genicular artery (D)
v, Saphenous vein
FLAP HARVEST

Design and Markings

The key landmark in saphenous flap design is the sartorius muscle, which runs along a line drawn from the anterior superior iliac spine to the medial epicondyle of the tibia. Before the skin paddle is designed, the dominant vascular pattern for that patient is identified by handheld Doppler examination or angiography. The proximal flap margin is drawn 10 cm above the knee joint; the distal margin will depend on the reconstructive need. Primary closure can be obtained in flaps 6 cm wide or less.

**Fig. 12B-3**  
A, If the anterior or “early” cutaneous branches of the saphenous artery predominate, the saphenous flap skin paddle should be designed more anteriorly and proximally to ensure that these vessels are included. B, When the anterior branches of the saphenous artery are deficient, the skin paddle must encompass the posterior branches and the distal continuation of the saphenous artery to ensure adequate circulation.
Patient Positioning
The patient is placed in the supine position with the knee flexed; the lateral decubitus position is also acceptable. A tourniquet is placed on the proximal thigh.

Fig. 12B-4

Frog-leg positioning with pads securing ankles
GUIDE TO FLAP DISSECTION

The first incision is made in the medial thigh over the sartorius muscle.

A 10 cm incision is made along the course of the sartorius above the planned flap. The medial femoral cutaneous nerve and greater saphenous vein are first isolated near the anterior and posterior borders of the sartorius.

The anterior border of the sartorius muscle is identified; the medial femoral cutaneous nerve, which parallels the anterior border of the sartorius, should be identified and spared. Deep fascia over the sartorius muscle is incised and dissected off its anterior portion. At the posterior border, the greater saphenous vein must be carefully preserved. The muscle is then reflected so that a blunt dissection can be performed and the saphenous artery be identified.

The deep fascia is incised and the sartorius muscle is bluntly dissected in the upper part of the incision and separated from the vastus medialis to expose the saphenous neurovascular bundle.
Next, the saphenous artery is traced distally and the locations of its cutaneous perforators determined. Once perforators are confirmed to be within the flap design, the distal flap can be incised and explored. Because of the variability of anatomy, there may be several options for vascularizing the flap. If the surgeon thinks the perforators anterior to the sartorius muscle are dominant, exploration continues anteriorly, and the flap is raised from anterior to posterior over the sartorius muscle. If it is thought that both the anterior and posterior perforators are approximately equal, a section of sartorius muscle is taken with the flap, and both sets of perforators are included in the flap. In some cases the anterior perforators are not present, and the flap must be perfused by the posterior branches; then the surgeon includes branches of the distal saphenous artery, which give off cutaneous branches below the insertion of the sartorius tendon.

Once the source of vascularization is ensured, the skin incision is completed. If the saphenous vein will be included as venous drainage for the flap, it is dissected proximally until an adequate length is obtained, and it is divided. The sartorius artery can be followed to the adductor canal, which yields a pedicle length of 15 cm.

**Fig. 12B-5**  
C, The sartorius muscle is then retracted inferiorly and medially, exposing the subsartorius canal. The saphenous artery and nerve are exposed and traced distally. If direct inspection reveals adequate anterior cutaneous branches, a skin paddle is appropriately traced to include these branches. If no anterior branches are found, the skin incision is extended more distally to within 6 cm of the knee. A flap is then outlined more distally and posteriorly on the distal saphenous artery.  
D, With distal placement of the cutaneous paddle over the distal saphenous artery or its posterior branches, division of the sartorius tendon or muscle harvest may be required to ensure an adequate blood supply.
FLAP VARIANTS

- Reverse saphenous flap
- Sensate flap
- Osteofasciocutaneous flap (medial femoral condylar flap)

Reverse Saphenous Flap
As noted earlier, there is a rich collateral anastomosis between the descending genicular artery and the superior and inferior genicular arteries. Because of this interconnection, proximal division of the saphenous and descending genicular arteries allows continued perfusion of the flap through this retrograde flow. In general, the skin paddle will be located more proximally than for a standard saphenous flap to allow pedicle length for rotation. In this case, dissection is initially posterior, with identification of the saphenous artery and confirmation of the cutaneous perforators within the flap design. The proximal incision is made and at this point the saphenous artery and vein are divided. The key communication for this reverse flap is the communication of the saphenous artery with the medial inferior genicular artery below the knee.

![Diagram of the reverse saphenous flap](image)

**Fig. 12B-6**
**Sensate Flap**
By inclusion of an appropriate cutaneous nerve, a sensate flap can be used for reconstruction. Inclusion of the branches of the medial femoral cutaneous nerve will provide sensation to a proximally based flap. Sensation to a flap positioned distal to the knee joint would require inclusion of the saphenous nerve. This does allow a long length of nerve; however, the downside is that innervation of the saphenous distribution of the lower leg and foot is interrupted. If sensory innervation is desired for the entire flap, both above and below the knee, both nerves should be harvested; if a free flap is required, it is reinnervated at the recipient site.

![Elevation of neurosensory island flap with both medial femoral cutaneous and saphenous nerves](image)

*Fig. 12B-7*
Osteofasciocutaneous Flap
(Medial Femoral Condylar Flap)
A section of bone can be harvested based on the osteoarticular branch of the descending genicular artery. This vessel supplies the periosteum and cortex of the medial supracondylar area of the femur. A cortical-cancellous segment of bone can be carried which measures 8 by 1.5 by 1.5 cm. One advantage of this flap compared with others is the independence of the skin and bone components and the lengthy vessels, which allows independent positioning without constraint.
ARC OF ROTATION
Proximally based flaps can cover the anterior knee and the popliteal fossa. Distally based flaps are particularly useful for the knee and defects of the upper third of the leg.

FLAP TRANSFER
Standard Flap
The standard flap can be transferred as a direct transposition or can be passed through a subcutaneous tunnel. The tunnel must be of adequate size to prevent compression of the vascular pedicle.

Reverse Flap
The reverse flap is usually transferred as a transposition flap by connecting the donor site and recipient site with an incision. It is more difficult to create a subcutaneous tunnel when crossing the knee joint, although in some cases it may be desired.

FLAP INSET
Flaps should be secured to the recipient sites without tension and without kinking or torsion of the pedicle.

Free Flap
The vascular pedicle supplied with the flap is lengthy with a good diameter. Tension-free microvascular anastomosis and adequate pedicle length must be ensured to prevent torsion or kinking from excessive length.

DONOR SITE CLOSURE
All Flap Variants
Flaps 6 cm or less in diameter can be closed primarily, with subcutaneous undermining to facilitate this. Otherwise, a skin graft can be used to close the donor site.
CLINICAL APPLICATIONS
This patient presented with a skin defect over the right malleolus.

Fig. 12B-10  A, The patient had a 10 by 6 cm skin defect over the right malleolus. B, Flap design. C, The flap was elevated on its pedicle (SM, sartorius muscle; AM, adductor magnus tendon). D, Appearance of the flap on postoperative day 5. E, The result is seen 18 months postoperatively. (Case courtesy Sebat Karamürsel, MD.)
This 45-year-old man had proximal phalanx nonunion of the ring finger of his right hand. A medial femoral condyle (MFC) corticoperiosteal flap was planned.

Fig. 12B-11 A, Medial approach to the distal femur. Note the length and caliber of the descending genicular artery and veins. B, Corticocancellous bone and skin components on the descending genicular artery pedicle. C, Preoperative oblique radiograph showing the proximal phalanx nonunion. D, The skin segment of the flap inset on the ulnar border of the hand. E, The postoperative radiographic result is seen at 8 weeks and F, 4 months. (Case courtesy James P. Higgins, MD.)
This 27-year-old patient had proximal ulnar nonunion.

Fig. 12B-12  A and B, Radiographs of proximal ulnar nonunion. C and D, A large 8 cm corticocancellous segment with skin paddle was raised; the skin was perfused by the distal cutaneous branch of the descending genicular artery. E, The result is seen on radiographs 8 weeks and F, 12 weeks postoperatively. G and H, After the ulna healed, the patient’s pronation and supination were fully restored. (Case courtesy James P. Higgins, MD.)
This 65-year-old patient presented with radius nonunion. An MFC flap was planned.

Fig. 12B-13  A and B, Preoperative radiographs demonstrate radius nonunion with plate fixation. C-E, Harvest site of the medial femoral condyle bone flap. The skin paddle and bone component are shown on the common descending genicular artery pedicle.
Fig. 12B-13  F and G, The results are seen radiographically at 4 weeks postoperatively; H and I, 8 weeks postoperatively; and J, 14 weeks postoperatively. (Case courtesy James P. Higgins, MD.)
This 55-year-old patient had an extensive carpal osteomyelitis defect after debridement.

**Fig. 12B-14**  
A, The defect is seen preoperatively.  
B, Flap design.  
C, Descending genicular artery with distal cutaneous branch at the level of the condyle (arrow).  
D, A large rectangular corticocancellous flap was raised (tourniquet released) and the defect was skin grafted.  
E and F, AP and lateral radiographs of the knee after harvest of the large medial femoral condyle bone segment.  
G-I, Radiographic views 10 weeks postoperatively. (Case courtesy James P. Higgins, MD.)
**Pearls and Pitfalls**

- It is essential to identify the dominant blood supply for the particular patient at hand, because there is significant variability of anatomy in this area. In other words, the surgeon must know the location and size of the perforators before fully committing to a flap design.
- The saphenous artery may be absent in up to 5% of patients.
- This is a useful flap when a thin, neurosensory flap is required.
- The donor site scar may be undesirable in women and children.
- Two major lymphatic trunks run the length of the flap with the saphenous vein. This may have potential uses in the future for lymphatic bypass.

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**EXPERT COMMENTARY**

**Sebat Karamürsel**

**Anatomic Considerations**

Skin over the medial side of the knee joint was first used by Acland et al as a free flap. The medial side of the knee joint provides a thin skin, especially if the flap is planned distally. The medial femoral cutaneous nerve or saphenous nerve may be used if a sensory flap is needed. If above-the-knee skin is elevated, the saphenous nerve must be preserved, although it lengthens the operation. If below-the-knee skin is elevated, the medial femoral cutaneous nerve must be preserved.

The saphenous flap has a long, wide arterial pedicle and an extraordinarily long venous pedicle if the great saphenous vein is used. An arterialized venous flap may also be planned based on the great saphenous vein. The donor site scar is relatively inconspicuous, especially if the defect is closed primarily. This flap may also be suitable for knee defect coverage if used as an island flap.

**Reference**


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**EXPERT COMMENTARY**

**James P. Higgins**

**Indications**

The medial femoral condyle (MFC) corticoperiosteal flap has received increasing attention for many applications since it was originally described in 1991. The favorable characteristics and osteogenic capabilities of the flap have led to its use in long bone nonunions, metacarpal and phalangeal nonunions, carpal and tarsal nonunions and avascular necrosis, and calvarial, orbital, and maxillary/mandibular defects. It is conventionally regarded as a pliable cortico
periosteal vascularized flap that may be molded and contoured around small nonunion sites with small or no bone deficits. It can provide a solution for recalcitrant nonunions when larger, well-established vascularized bone flaps (such as the fibula and iliac crest) would result in higher morbidity or create difficulty in their application to small or irregularly shaped bone defects. The MFC flap has gained attention in the treatment of recalcitrant scaphoid nonunions when the use of other free vascularized bone flaps is not possible.

Recent studies demonstrate continued expansion of the indications for the use of this flap to include its use as a corticocancellous semistructural flap. Literature reports have included corticocancellous segments of up to 10 cm in length. Recent selective injection studies have indicated that the descending genicular artery (DGA) can provide perfusion for the distal 13.7 cm of the medial femur, suggesting that this may be the limit of this flap’s utility for larger osseous defects.

**Advantages and Limitations**

This flap has provided a low morbidity alternative to vascularized bone harvest in comparison to other free bone harvest sites. Unlike the fibula flap, for example, this flap can preserve the integrity of the remaining femur; avoid sacrificing a major vessel to the distal extremity; be harvested in various thicknesses and configurations for various defects (such as the pliable corticoperiosteal flap for onlay around nonunions without segmental bone loss or trapezoidal corticocancellous flaps for wrist or ankle fusion defects); provide a generous skin paddle and still permit primary closure of donor site; provide a greater proportion of cancellous bone content; and be more conveniently harvested in the supine position during two-team surgery.

However, the corticocancellous ratio of the fibula shaft is significantly higher (0.65 versus 0.11) than the MFC, suggesting that the MFC would not provide the same structural characteristics if required for long bone cases. Additionally, the perfusion zone of the DGA (13.7 cm of the medial column of the femur) limits the length of osseous defects that can be treated with the MFC to small- and medium-length deficits.

**Anatomic Considerations**

Although the saphenous artery has been described as the skin-perfusing branch of the osteocutaneous MFC flap, the saphenous artery may originate from the superficial femoral artery separate from the descending genicular artery in a minority of cases. Additionally, the DGA may be absent in some cases, leaving the MFC flap perfused by the superomedial genicular artery. In both of these situations, the use of the chimeric saphenous artery and MFC flap would not be possible.

The skin overlying the MFC also receives perfusion from a smaller and more distal cutaneous vessel that can be seen branching from the DGA at the level of the condyle (descending genicular artery cutaneous branch: DGA-CB). This can be used as an alternative source of skin perfusion for the osteocutaneous MFC flap.

**Personal Experience and Insights**

The use of the MFC bone flap has been described most often without a skin component. In the first 100 cases described in the literature, fewer than 20 were osteocutaneous flaps. In my experience, the routine use of the skin component of this flap provides two important advantages: first, it permits accurate monitoring of the underlying bone perfusion, particularly in the first critical days after transfer; second, an advantage is gained by tension-free skin closure over the anastomosis. In areas around the distal extremities (hand/wrist/foot/ankle), closure after complex reconstructive and microsurgical cases may be difficult without
the additional skin paddle. Routine use of the skin component requires a thorough understanding of the saphenous artery flap and the anatomy of the distal cutaneous skin branches of the DGA.

**Recommendations**

**Planning Considerations and Technique**

The flap dissection is approached with the intent of harvesting a skin paddle regardless of the variations in anatomy. A sweeping curvilinear incision is created starting at Hunter’s canal and moving distally and anteriorly to the midpoint between the medial border of the patella and the MFC, where it continues distally and posteriorly, stopping 2 to 3 cm below the joint line and just posterior to the midaxis of the leg. This skin incision is continued to the subfascial plane of the vastus medialis muscle, which allows the skin paddle to be rapidly elevated and retracted posteriorly as the vastus medialis is dissected anteriorly. The DGA can then be identified as the medial column of the femur is exposed.

Dissecting subfascially ensures protection of all skin vessels that may branch off the distal DGA into the reflected skin. Through the fascial plane of the vastus medialis the branching vessels emitting from the DGA can be identified, and the presence or absence of the saphenous artery branching from the DGA and/or DGA-CB is rapidly noted. Branches to the vastus medialis course anteriorly (penetrating the fascial plane) and are suture ligated. At this point, a decision is made regarding the approach for the skin paddle.

In most of my cases, the DGA-CB is selected if it is present, regardless of the presence of the saphenous artery. This skin vessel may be preferable because of the speed with which it can be dissected as well as the assurance that the skin and subcutaneous vasculature can be elevated anterior to the sartorius muscle and adductor tendon, keeping the skin and bone segments in the same dissection interval (between the vastus medialis and sartorius muscles). If the saphenous artery is selected as the means of supplying the skin segment, a careful distal dissection is required to determine whether the artery is supported by skin branches that pass anterior to the sartorius muscle (45%) and in the same surgical interval as the bone component, or posterior to the sartorius muscle (55%). If it does pass posteriorly, it will require a distal elevation of the skin segment and careful passage deep to the sartorius muscle to reunite it with the bone segment before flap harvest is completed.

When treating recalcitrant nonunions in closed soft tissue, the skin segment used for MFC to permit ease of closure and monitoring is usually less than 4 by 8 cm, and primary closure of the donor site is possible. The smaller skin paddle available from the DGA-CB serves the surgeon well in this setting. The saphenous artery, in contrast, has a larger angiosome and provides a greater freedom of insetting, distinct from the bone segment, because of its proximal branching point. If the surgeon chooses to use this flap to both provide vascularized bone and soft tissue coverage of extensive wounds, the extent of the angiosome of the saphenous artery branch may make it a wiser choice for the reconstructive surgeon than the DGA-CB.

A Doppler signal is usually easily audible over the apex of the MFC when the skin flap is returned to its anatomic position. The initial sweeping incision allows many variations of oblique or longitudinally oriented ellipses to be designed using the initial incision as the anterior border of the skin component, capturing the Doppler signal for postoperative monitoring. Care is taken to harvest this so that primary closure can be simply achieved.

The skin component is usually elevated first, then attention is turned to the bone segment. The bone segment is dissected in the width, length, and depth required, and the flap is harvested on the common DGA origin vessel.

*Continued*
Postoperative Care
Although patients seem to have less pain with the MFC harvest site compared with an iliac crest harvest, caution is required with ambulation if very large corticocancellous flaps are harvested. Even though a brace is inadequate in preventing torsional stresses on the femur, we often require patients to use hinged knee braces after larger harvests to protect the femur. In most smaller corticocancellous or thin corticoperiosteal harvest cases, no restriction or protection is required.

Complications
The most concerning complication of this flap is femur fracture after larger bone harvests. To prevent this complication, harvests are strictly limited to the cortical surface of the medial column of the femur. Harvest depth is also limited to avoid loss of support of the medial condyle. Excessive proximal harvest into the diaphysis of the femur is likewise avoided. Biomechanical studies to assess the risk of torsional stresses in larger harvests are needed.

Take-Away Messages
Since the landmark description of the saphenous skin flap in 1981 by Acland et al, its use has been limited by the substantial variation in the vascular anatomy and the later availability of more reliable donor sites. Interest in this flap has seen a rebirth with the growing interest in the subsequently described MFC bone flap from the shared vascular pedicle. A thorough understanding of this anatomy is critical for routine and reliable harvest of the skin component of this valuable vascularized bone source.

Bibliography With Key Annotations

The author reported on his further experience with the distally based saphenous flap and described a modification of the reversed saphenous flap, used in approximately 40 cases. Advantages included that the flap can be elevated with the patient in the supine position, it is fast and easy to execute, morbidity is reasonably low, and the flap can reach the Achilles tendon and malleolar regions and dorsum of the foot. The author stated that the flap should be considered among the flaps of first choice.


Finding an appropriate soft tissue grafting material to close a wound located over the ankle and heel can be a difficult task. The distally based lesser saphenous venofasciocutaneous flap mobilized from the posterior aspect of the upper leg, used as an island pedicle skin flap, can be useful for this purpose. The vascular supply to the flap is derived from the retrograde perfusion of the accompanying arteries of the lesser saphenous vein. These arteries descend along both sides of the lesser saphenous vein to the distal third of the leg, either terminating or anastomosing with the septocutaneous perforators of the peroneal artery. The authors used four variants of this flap in 21 individuals, including 11 fasciocutaneous, 5 fascial, 3 sensory, and 2 fasciomyocutaneous flaps. Skin defects among all patients were combined with bone, joint, and/or tendon exposure. They found that the flap was reliable and technically simple to design and execute. This one-stage procedure not only preserves the major arteries and the sural nerve of the injured leg, but it also has proved valuable for covering a weight-bearing heel and filling a deep defect, because it potentially provides protective sensation and a well-vascularized muscle fragment. When conventional local flaps are inadequate, this flap should be considered for its reliability and low associated morbidity.

An ideal way to treat osteoradionecrosis of the jae is to transfer an osteogenic, appropriately vascularized flap to the affected site. The corticoperiosteal femoral medial supracondylar flap is being used increasingly in the treatment of complex pseudarthrosis of long bones. However, robust indications have yet to be found for use in the treatment of osteoradionecrosis of the jaw, the reasons being a lack of anatomic data concerning its vascular supply and the local constraints of its routine harvest. The authors presented an anatomic study and literature review to explore its potentials in clinical practice. A total of 25 legs were dissected following vascular injection of colored neoprene. The descending genicular artery (DGA) and veins were studied with particular attention paid to anatomic variations found in their branches. Calibers and length of the vessels were recorded. Many anatomic variations of the DGA were found and a classification proposed. The mean caliber of the DGA at the origin was 1.9 mm, and for the vein, 1.8 mm. The mean useful length of the pedicle was 7.9 cm. A case was reported.


The authors responded to Dr. Cavadas’s article (above) and related their experience with the posterior tibial perforator–saphenous flap for Achilles tendon coverage. They concluded that the subcutaneous 180-degree turnover of the flap and exclusion of the greater saphenous vein are safer and must be done. In their case, they preserved the skin island, performing a double twist to the pedicle because the pedicle and tunnel were thin. They proposed ligation of the vein at the malleolus level to avoid possible injury to the pedicle at the base of the flap.


Neurocutaneous flaps based on the arterial network around the superficial sensory nerves are popular for soft tissue coverage of the lower extremities and are usually preferred in reconstruction of the lower leg and foot. Sacrifice of sensory cutaneous nerves is one of their major disadvantages, but morbidity in the foot and at the donor site had not been well investigated. The authors investigated sensorial morbidity in the foot and at the donor site caused by raising a saphenous neurocutaneous flap in 14 patients by using static two-point discrimination test, Semmes-Weinstein monofilament test, vibration test, and by measuring somatosensory evoked potentials after 12 months. Their results suggest that sensory recovery is good and protective sensation is gained in most patients.


The knee region is a good donor site for a free skin flap; it has minimal subcutaneous tissue and provides a hidden donor site. Acland et al first used the skin over the medial side of the knee as a saphenous flap based on the saphenous branch of the descending genicular artery. The authors studied the descending genicular artery and its saphenous branch in six cadaver limbs and elevated the skin over the medial side of the knee as a free flap in six patients to reconstruct lower extremity defects. In all clinical cases, they were able to elevate a skin flap from the skin on the medial side of the knee. All the flaps survived and the defects healed well.


The reconstruction of the heel represents a challenge because of the limited local soft tissue availability and the special structural and functional characteristics of this region. A great number of possibilities have been described; the authors presented a modified form of the sural fasciocutaneous flap for heel reconstruction. Ten patients (two female and eight male; median age 68 years, range 48 to 76) underwent reversed saphenous fasciocutaneous island flap after wide excision of a heel lesion. The causes of heel lesions in all patients were squamous cell carcinoma on a chronic burn scar. In this new technique, the sural nerve and artery were saved, and the blood supply to the flap was based on lesser
saphenous vein. The mean lesion surface was 60 cm² (range 30 to 112 cm²). Epidermolysis and flap discoloration were seen in three patients; this was treated with intermittent wet dressing and conservative management. One patient showed partial necrosis in flap circumference; this recovered with debridement and skin grafting. Total flap necrosis was not seen in any patients. Their mean hospital stay was 10 days (range 8 to 15 days). The mean follow-up was 12 months.


In reconstruction of the extremities, a distally based flap is useful for covering the distal parts. However, these flaps are prone to congestion in the peripheral part of the flap, followed by necrosis because of insufficient venous drainage as a result of resistance of the venous valves. To rescue venous congestion of a distally based flap, venous anastomosis is effective so that the venous blood flows in the direction of the venous valve. The authors applied this idea to a patient who had skin defects around the knee after a wide resection of a skin tumor and covered them with a distally based greater saphenous venoadipofascial–sartorius muscle combined flap. The whole area of the flap took well without congestion.


Although the saphenous flap has been used in reconstruction as a free flap, there has not yet been an anatomic study about the perforators of the saphenous artery. The aim of this study was to investigate the anatomy of the saphenous artery and the number and locations of its perforators. The authors dissected parts of 10 legs from five cadavers. Measurements of the positions of the dissected saphenous arteries and their perforators were taken from the medial epicondyle of the femur. They observed the origin, endpoint, and diameter of each of the arteries and investigated the numbers and locations of both septocutaneous and myocutaneous perforators. The average length of the saphenous artery was 14.8 cm, and it was located 12.0 cm above the medial epicondyle of the femur. The average diameter was 1.63 mm. A median average of four perforators branched out from a single saphenous artery. On average there were two septocutaneous perforators and two myocutaneous perforators from the saphenous artery, mainly located about 7 cm proximal to the medial epicondyle of the femur.


The authors presented a retrospective, noncontrolled clinical study of patients with lower leg postsurgical chronic osteomyelitis. All patients were treated with distally based saphenous neurofasciocutaneous perforator flaps, the feeding perforators originating from the tibial artery. An endpoint survey was conducted after flap surgery; the mean follow-up period was 4 years, the response rate 60%. Six patients had short-term flap failure (12%), and six had flap necrosis of less than one fourth of the flap that healed without surgical revision. Based on the endpoint data, the long-term success rate was 70% among respondents. The authors concluded that the saphenous perforator flap is a sturdy flap with low short-term failure rates, also in high-risk patients. Their success rate compared well with results of free flap transfers in the management of posttraumatic osteomyelitis. The saphenous flap is a feasible option for posttraumatic reconstructions of osteomyelitis, especially in low-resource settings.


For bony nonunions with poor skin coverage, transplantation of vascularized soft tissue in addition to bone graft is desirable. The use of the corticoperiosteal vascularized bone graft from the medial femoral condyle has been well described, but there have only been anecdotal reports about its use as an osteocutaneous flap. The authors presented results with the use of an osteocutaneous flap from the medial femoral condyle in four patients treated with supracondylar osteocutaneous flaps for bony nonunions (tibia, ankle, calcaneus) with concomitant soft tissue defects. The supplying cutaneous vessels were
an unnamed perforator of the descending genicular artery (two cases) or the saphenous branch (two cases). The first three cases healed primarily. Bony union was achieved between 32 and 170 days. The follow-up of the fourth case was too short to achieve a bony union. There was no flap loss and no surgery-related complications at the donor site.


Six patients with recalcitrant posttraumatic humeral shaft nonunions were treated using vascularized bone grafts from the supracondylar region of the femur. The initial state of injury showed that four fractures were closed, while two were open fractures. At the acute stage, five fractures were fixed using intramedullary nailing, while one was fixed with a plate. In all patients, a bony flap was placed on the cortex after decortication. The size of the harvested bone flap ranged between 4 by 2.5 cm and 5 by 3 cm. After fixation of the bony flap, the inferior genicular artery and vein were anastomosed to the deep brachial artery and vein. The mean time required to obtain radiographic bone union was 3.3 months. The only graft site complication involved transient mild paresthesia in the saphenous nerve area in one patient.


Neurocutaneous island flaps have been very popular in soft tissue coverage of the lower extremities. These flaps are based on the arterial network around the superficial sensory nerves. The advantages of these flaps are easy and quick dissection (hence a time-saving operation), acceptable donor site morbidity, and preservation of major arteries of the leg. The authors used five neurofasciocutaneous and three myofasciocutaneous flaps successfully as cross-leg flaps for the coverage of relatively large defects of the lower two thirds of the leg and foot in eight patients. They concluded that reverse saphenous neurofasciocutaneous and myofasciocutaneous flaps as a cross-leg flap in patients who cannot be reconstructed with other flap alternatives have many advantages over traditional cross-leg procedures, such as short vascularization time, minimal patient discomfort, wide arc of rotation, great versatility, and a safe vascular pattern.


The distally based sural neurovenofasciocutaneous flap has been used widely for reconstruction of foot and ankle soft tissue defects. The distal pivot point of the flap is designed at the lowest septocutaneous perforator from the peroneal artery of the posterolateral septum, which is on average 5 cm (range 4 to 7 cm) above the lateral malleolus. A longer neurovenoapipofascial pedicle would be needed to reversely reach the distal foot defect when the flap is dissected based on this perforating branch, which may result in more trauma in flap elevation and morbidity of the donor site. The authors explored new pivot points for this distally based flap in an anatomic study of 30 fresh cadavers. The results showed that the peroneal artery terminates into two branches: the posterior lateral malleolus artery and lateral calcaneal artery. These two branches also send off cutaneous perforators at about 3 and 1 cm above the tip of lateral malleolus, respectively, which can be used as arterial pivot points for the flap. A communicating branch between the lesser saphenous vein and the peroneal venae comitantes was found, accompanied by the perforator of the posterior lateral malleolus artery. This modified, distally based sural flap with lower pivot points was successfully transferred for repair of soft tissue defects in 21 patients. The authors stated that the vascular pivot point of a distally based sural flap can be safely designed 1.5 cm proximal to the tip of the lateral malleolus.
ANATOMIC LANDMARKS

**Landmarks**
Inner thigh, from pubis to medial tibial condyle.

**Size**
$30 \times 5 \text{ cm} \times 2 \text{ cm}$ thick.

**Origin**
The pubic symphysis; it can be found just below the tendon of origin of the adductor longus muscle, which is palpable near the pubic tubercle.

**Insertion**
Inserts into the medial tibial condyle immediately posterior to the sartorius muscle.

**Function**
Adducts the thigh.

**Composition**
Muscle, myocutaneous, or fasciocutaneous.

**Flap Type**
Type II.

**Dominant Pedicle**
Medial circumflex femoral artery.

**Minor Pedicle**
Perforating vessels from the deep femoral artery or superficial femoral artery.

**Nerve Supply**
Section 12C

THIGH

Gracilis and TUG/TMG Flaps

CLINICAL APPLICATIONS

Regional Use
- Lower abdomen
- Pubis
- Groin
- Perineum
- Ischium

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Functional muscle for upper extremity
- Functional muscle for facial reanimation
- Anal sphincter reconstruction
- Vaginal reconstruction
ANATOMY OF THE GRACILIS FLAP

Muscular anatomy of gracilis flap

Arterial system and nerve supply of gracilis flap

Fig. 12C-1

Dominant pedicle: Medial circumflex femoral artery
ANATOMY

**Landmarks**
The gracilis muscle lies between the pubic bone, just below the pubic tubercle, and the medial surface of the tibia.

**Composition**
Muscle, myocutaneous, or fasciocutaneous. The muscle is commonly used for reconstruction because it is expendable and has a relatively large vascular bundle for a relatively small muscle.

**Size**
30 cm long, 5 cm wide, 2 cm thick, depending on the size and build of the patient. The gracilis muscle has distinct tendons of origin and insertion that can lengthen its functional length up to an additional 8 cm.

**Origin**
The pubic symphysis; specifically the aponeurosis originates along the pubic arch, along the body and inferior ramus of the pubis, below the pubic tubercle. It can be found just below the tendon of origin of the adductor longus muscle, which is palpable near the pubic tubercle.

**Insertion**
The gracilis muscle inserts into the medial tibial condyle immediately posterior to the sartorius muscle.

**Function**
The gracilis is a straplike muscle that adducts the thigh. There is no discernible loss of adduction of the thigh after the muscle has been harvested.

### Arterial Anatomy (Type II)

#### Dominant Pedicle
*Medial circumflex femoral artery*

**Regional Source**
Deep femoral artery.

**Length**
7 cm.

**Diameter**
1 to 2 mm.

**Location**
Enters lateral aspect of muscle from between adductor longus and adductor magnus. Enters muscle in two or three terminal branches 10 cm inferior to the pubic tubercle.

#### Minor Pedicle
*Smaller branches of the deep femoral artery or superficial femoral artery*

**Regional Source**
Deep femoral artery or superficial femoral artery.

**Length**
2 to 3 cm.

**Diameter**
0.5 mm.

**Location**
Distal half of the muscle.

### Venous Anatomy

There are two venae comitantes that run with the medial circumflex femoral artery. External diameters are 1.5 to 3 mm, with a length of 6 cm. When the proximal transverse skin island is used, one can capture the greater saphenous vein, which can be used as secondary venous outflow, particularly in a free tissue transfer.

### Nerve Supply

#### Motor
The obturator nerve enters the gracilis muscle on its medial surface immediately superior to the medial circumflex femoral vessels. Its course proximally diverges from the vessels, running obliquely, then superiorly. The average nerve length that may be taken with the flap is 7 cm.

#### Sensory
The anterior femoral cutaneous nerve arising from L2 to L3 provides sensation to most of the anterior medial thigh. A small cutaneous branch of the anterior obturator nerve arises in the vicinity of the vascular pedicle and passes deep to the adductor longus muscle. This branch must be carefully dissected to avoid paresthesia in the distal medial thigh.
**Vascular Anatomy of the Gracilis Flap**

**Fig. 12C-2**

*Dominant pedicle:* Ascending branch of medial circumflex femoral artery (*D*)

*Minor pedicle:* One or two branches of superficial femoral artery (*m*)

*n,* Obturator nerve

Deep surface of flap

Radiographic view
FLAP HARVEST

Design and Markings

Muscle-only harvest is best accomplished through a linear incision overlying the muscle. A line can be drawn from the adductor tendon at the medial pubic tubercle to the medial femoral condyle. The gracilis muscle lies just posterior to this. In a prone position, the incision would lie more posterior to aid in wound closure.

For a myocutaneous flap, a longitudinal skin island is most commonly used and should be centered posterior to this line. The skin island becomes unreliable in the distal third of the leg and should only be used if a delay procedure is performed.
The transverse skin paddle is often used in breast reconstruction; it is called the transverse myocutaneous gracilis (TMG) or transverse upper gracilis (TUG) flap. The design for this flap starts at the groin crease and extends a variable distance inferiorly to allow primary closure, usually 10 cm long. A fleur-de-lis design is also possible, taking advantage of both horizontal and vertical excess in the thigh, in exchange for a larger scar.

Forceful abduction of the thigh will help to visualize the adductor longus muscle; this can be marked in the holding area. Placing the leg in a frog-leg position in the operating room will also allow the surgeon to palpate the adductor longus muscle and tendon. After marking a line from the adductor tendon origin to the medial femoral condyle of the femur, a linear incision is planned for muscle harvest or an elliptical skin flap design is planned, centered posterior to this line. The skin to be harvested is grasped to determine how much flap can be harvested with primary closure. A flap of 9 cm in width can usually be closed primarily.
Patient Positioning
The versatility of the gracilis muscle for reconstruction is that it can be harvested in a variety of positions, depending on need. For most anterior abdomen, pubic, and perineal applications, a lithotomy position can be used with the patient’s legs in stirrups. For most head and neck applications, harvest can be performed in a supine position and frog-leg position. For applications of the perineum, such as an anal sphincter or rectovaginal fistula repair, a prone position can be used. However, although the prone position can be used to harvest the muscle through a more posterior incision, which allows closure, harvesting of a skin paddle and closure of the leg is not recommended in this position.

Fig. 12C-4
GUIDE TO FLAP DISSECTION

With the patient supine and the knee and hip slightly flexed, an incision overlying the gracilis muscle is made. The first, most superficial structure encountered is the greater saphenous vein, which should be preserved if possible. Deepening the incision through muscular fascia allows identification of the gracilis muscle. The gracilis is the posteriormost adductor of the leg. Care should be taken in the distal half of the leg to identify the muscle with certainty, because the sartorius muscle often overlies the gracilis in this area and has a similar appearance. It can be helpful to initially make an incision over the insertion of the gracilis distally and apply traction to the gracilis tendon to aid definitive identification. The gracilis runs toward the pubic tubercle, whereas the sartorius runs toward the ASIS. This maneuver is most helpful when ensuring proper placement of the skin paddle relative to the muscle. More proximally, the muscle is readily identified immediately posterior to the adductor longus muscle. The key to recognizing the muscle is confirming the positions of the medial circumflex femoral pedicle and the obturator nerve, which conclusively identifies the muscle.

Once the vascular pedicle and nerve have been identified, the remainder of the dissection is more straightforward. Dissection may then quickly proceed on the medial surface of the muscle from origin to insertion. Next, the distalmost portions of the muscle are dissected, dividing the minor pedicles as they are encountered.
It is helpful when dissecting the medial circumflex femoral vessels to take the fascia investing the adductor longus muscle. This allows an easy dissection that both exposes and protects these vessels.

Fig. 12C-5
To rotate the flap, the medial circumflex femoral pedicle marks the rotation point, and the distal insertion can be divided at the tendon and the muscle rotated superiorly.

For free tissue transfer, less muscle harvest may be required, and only the proximal portion of the incision may be needed. When division of the muscle is required proximally, division at the fascial origin is bloodless and straightforward. If further lengthening of the arc of rotation is necessary, dissection of the medial circumflex femoral pedicle will add an additional 2 cm of reach. Care must be taken to divide branches to the adductor longus muscle that emanate from this pedicle. In most cases of transposition, division of the origin will not add any further length to the arc of rotation of the flap. In rare circumstances in which the arc of rotation is insufficient after these maneuvers, the medial circumflex femoral pedicle can be divided, and the muscle may survive off perforating vessels around the origin of the muscle. Microvascular clamps can be placed on the pedicle to test the more proximal blood supply. However, it is preferable to always maintain the medial circumflex femoral pedicle when possible.
FLAP VARIANTS

- Myocutaneous flap
- Medial circumflex femoral artery perforator (TUG/TMG) flap
- Functional muscle

Myocutaneous Flap

Early investigators thought that the skin paddle associated with the gracilis muscle was unreliable, because the muscle is relatively small, and depending on the patient’s anatomy, a small ellipse of skin may not be properly placed into the angiosome of the perforators of the medial circumflex femoral vessels. The muscle also is deep distally and is based off its minor blood supply, so the skin paddle was thought to be reliable only in the proximal two thirds of the leg. With further anatomic study and experience, the skin paddle can now be harvested reliably. Two maneuvers are most helpful in accounting for this reliability: localizing perforators with Doppler ultrasound, and harvesting the investing fascia of all surrounding muscles with the flap.

Perforators of the medial circumflex femoral artery are most commonly located 10 cm distal to the pubic tubercle. Anatomic variation exists within this area, and more than one perforator may be present. The perforator may run through the gracilis muscle proper or just anterior or posterior to it. Skin paddle design should encompass these Doppler points. When dissecting the skin flaps, dissection should proceed down to the muscular fascia overlying adductor longus and overlying semitendinosus muscles. Dissection should proceed down through the fascia and then inward toward the flap, along the side of the adductor longus. This will carry the dissection directly into the septum where the medial femoral vessels and obturator nerve reside. Posteriorly, capturing this investing fascia ensures that perforators to the skin flap that arise posterior to the gracilis muscle will still be included. Once the flap has been dissected onto this mesentery, it may be dissected from distal to proximal, with care being taken not to injure the medial circumflex femoral vessels. As a rotational flap, further lengthening can be performed as described previously.

![Completed dissection of a myocutaneous gracilis flap.](image)
Medial Femoral Circumflex Artery Perforator (TUG/TMG) Flap

The tissues normally removed during a medial thigh lift can be harvested as a perforator free flap sparing gracilis muscle. Alternatively, the flap can be harvested with a variable amount of muscle to protect perforating vessels or to add bulk to the flap. Flap design should be similar to that of a medial thigh lift, and additional bulk may be added to this flap by creating a fleur-de-lis design. The actual design of this flap will vary, depending on the patient’s anatomy and desire for placement of the donor site scar. When used as a perforator flap, the perforators are identified preoperatively using a handheld Doppler probe. The design of the flap is shifted posteriorly to capture the better-vascularized and more abundant skin and fatty tissue that reside posteriorly and encroach upon the gluteal area. Anteriorly, there should be minimal dissection over the femoral triangle, because there are minimal tissues and important lymphatics that should be spared. The angiosome of these perforators from the medial circumflex femoral system does not extend anterior to the femoral vessels.

Dissection starts anteriorly. The ellipse of skin overlying the femoral triangle, which is marked largely for dog-ear management, is removed only in the subcutaneous plane. Once beyond the femoral triangle, the plane is then deepened to the adductor fascia, which can be included with the flap. For perforator flaps, careful dissection then proceeds above the gracilis muscle, with identification of the perforator. For flaps that include muscle, anterior dissection of the muscle can be performed. Next, attention is directed posteriorly, where the flap may be rapidly incised and raised up to the point of the perforating vessel. If a single perforator of large size is not found, several adjacent medium-sized perforators must be dissected through the muscle. These perforators generally join together within the muscle. The dominant pedicle lies directly opposite the intramuscular course of these perforators, and careful intramuscular dissection is essential to avoid injury. Once the perforators have been dissected, the remainder of the flap attachments can be removed. The saphenous vein can be taken with the flap as an alternative venous outflow, although this is usually not necessary. When muscle is harvested with this flap, especially to increase bulk, the previous guidelines for dissecting the muscle should be used.

![Fig. 12C-7](https://example.com/fig12c7.png)

**Fig. 12C-7**
Thigh • 12C: Gracilis and TUG/TMG Flaps

Fig. 12C-7

Initial anterior dissection of TUG flap, superficial over femoral triangle, sparing the saphenous or intentionally including it in flap

Posterior dissection, subfacial to gracilis; either perforator-only or segmental muscle harvest (pictured) dissection isolates the flap on its pedicle

Flap raised from distal to proximal, isolating it completely on medial circumflex femoral pedicle
Functional Muscle
The gracilis muscle can be used as a functional muscle either as a regional rotation or as a free tissue transfer. As a regional rotation, the dissection of the flap is performed as discussed earlier for a standard flap. The surgeon must exercise care to avoid injuring the obturator nerve, which is critical to the harvest of this functional muscle. When the muscle is being used for anal sphincter reconstruction, a subcutaneous tunnel is created from the donor site toward the recipient site, where the muscle can be passed and then wrapped around the anus to provide sphincter function.

When the muscle is being used as a free tissue transfer, the length of the desired muscle can be determined from the recipient site’s needs. It is important to mark the muscle at its resting length before harvest. The muscle may be taken in its entirety, as is often the case for upper and lower extremity uses. The muscle may also be split to a smaller size, as is commonly done for facial reanimation. When harvested for free tissue transfer, care must be taken not only in dissecting the vascular pedicle to its source, but also in dissecting the nerve as proximally as can be followed. Both of these maneuvers will greatly facilitate muscle inset. Full dissection of the medial circumflex femoral artery to its source is recommended, because the artery tends to be quite small and enlarges in size at its origin.

Fig. 12C-8

Subcutaneous tunnel

Rotational flap for rectovaginal fistula, anal incontinence, and genitourinary applications

Rotational flap for anal sphincter reconstruction
ARC OF ROTATION

Standard Flap

The muscle, based on its medial circumflex femoral blood supply, can be rotated superiorly for defects in the lower abdomen, pubis, groin, perineum, and ischium. Depending on the reconstructive need, it should be kept in mind that the muscle tapers at its distalmost part and is largely tendinous at its distalmost insertion; therefore, as tissue needs require muscle farther from the medial circumflex femoral pedicle, the less skin and less muscle bulk will be available for reconstruction. If a greater skin flap is required, a delay procedure should be performed. Rotation of the flap distally based on its minor pedicle is not recommended without surgical delay.

Fig. 12C-9

Arc to groin

Arc to perineum

Arc to ischium
FLAP TRANSFER

Standard Flap
The muscle or myocutaneous tissues will reach the recipient site either through direct transposition through an open wound or through a subcutaneous tunnel. When rotating the flap through a subcutaneous tunnel, the surgeon must ensure adequate space for the flap without compression. The tunnel is located in the subcutaneous plane. The flap may easily rotate through 180 degrees without vascular compromise. Care should be taken to prevent tension on the vascular pedicle during closure.

FLAP INSET

Pedicle Flap
The rotated flap should be inset without tension or kinking of the vascular pedicle. Division of the origin of the muscle is not required and may add vascularity to the flap if left in situ. Depending on the reconstructive need, the surgeon should consider division of the obturator nerve to limit muscular contraction postoperatively as well as displacement of the reconstructive tissues. In passing the flap through a tunnel, it is helpful to secure the muscle to the tunnel where it emerges to prevent retraction of the muscle postoperatively.

Free Flap
For wound applications, the surgeon must ensure that the muscle used for inset has excellent vascularity. It is appropriate to place the muscle on some tension to best distribute it. Muscle free flaps used for wounds often require skin grafting. When skin and muscle are used for applications such as breast reconstruction, care must be taken to anchor tissues to prevent tension on the anastomosis postoperatively. The elliptical design of the TUG flap lends itself nicely to contouring into a breast shape. The surgeon must ensure vascularity to all areas of the skin paddle before inserting the flap. It is not uncommon that the extension of the skin near the femoral triangle has poor vascularity, and this often requires removal before inset. As a functional muscle transfer, it is critical to inset the flap at its resting length for best postoperative function. For muscle transfer to an extremity, it is often helpful to carry the skin paddle with the flap to allow tension-free closure. After the functional muscle has been placed, this is often in a scarred or contracted bed, where extra skin is required for a closure that will not put pressure on the microscopic anastomosis. The skin paddle can often be excised at a later time if it is deemed unaesthetic or bulky.

For facial reanimation, it can be useful to carry the tendinous origin of the muscle with the flap, because this area will hold sutures better than a cut muscle edge. Again, care must be taken to make certain that the isolated segment of muscle being transferred has excellent innervation and vascularity to ensure a functional result.

DONOR SITE CLOSURE
Primary closure of this donor site is the norm for standard muscle flaps; simple closure with reapproximation of Scarpa’s fascia as well as the skin is straightforward. Because of the lymphatic vessels in this area, it is recommended that a drain be placed in all these donor sites of the upper thigh and to keep these in place until drainage is minimal. Harvest of a skin paddle of 9 cm diameter can be closed primarily. Larger flaps, especially after flap delay, may require a skin graft for donor site closure. If a larger skin paddle is required, one should consider other flaps, such as the ALT flap, for better vascularity of a large skin paddle. Transverse skin designs are closed in a manner similar to that for medial thigh lifts. Anchoring in the Scarpa’s fascial layer is essential for taking tension off the skin closure. Any cheating
of the skin closure with wrinkling of the skin is performed posteriorly, where it is less visible. When a flap is harvested from only one leg, there is little irregularity of the donor site contour. When a large skin paddle is harvested, there may be an asymmetry that requires contralateral liposuction or contralateral skin excision to restore balance. Fortunately for most patients, any such deformities can be hidden in clothes and therefore additional work to restore symmetry is not usually required.

**CLINICAL APPLICATIONS**

This 59-year-old woman had a history of vulvar cancer and had undergone radiation therapy. She had a radical resection, leaving a complex irradiated wound with an exposed pubic bone, and a partial vaginectomy. A myocutaneous gracilis flap was a good choice for reconstruction in this patient, because it offers ample available tissue in a donor site with minimal morbidity. Other options included rectus abdominis, TFL, and rectus femoris flaps.

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**Fig. 12C-10**  
A, The defect after wide resection. Some of the pubis was saucerized and is exposed. No further urethral reconstruction was deemed necessary.  
B, Design of the gracilis myocutaneous flap. The tendon has been identified and placing tension on the tendon helps locate the skin paddle design.  
C, The flap has been transposed through a subcutaneous tunnel and is inset. There was some early congestion that might have been avoided by connecting the donor and recipient sites and directly transposing the flap.  
D, The patient at 4-month follow-up. Despite a well-healed wound and donor site, the patient has difficulty with hygiene when urinating. (Case supplied by MRZ.)
This 19-year-old woman sustained a severe open fracture of the ankle in a motor vehicle accident. The gracilis is a favored choice for reconstruction of a traumatic injury in the distal third of the leg, since there are no good local muscle flap options. If the wound is too large for a gracilis muscle, other larger muscles can be considered, such as the rectus abdominis and latissimus dorsi.

Fig. 12C-11  A, A multilevel injury with radiographically documented distal fractures. Three-vessel runoff was noted on a preoperative angiogram. The proximal wound was skin grafted. B, Closeup of the wound with exposed articular surface. All nonviable tissues were debrided. C, After inset of the gracilis free flap. Microscopic anastomosis was performed to the posterior tibial vessels. The muscle was used to completely fill and seal the wound, and the muscle was then skin grafted. Before the flap was placed, an external fixator was used for fracture fixation. D, The ankle at 4-month follow-up. The contour is good, with muscle atrophy and contracture of the meshed skin graft. No surgical revision was required. (Case supplied by MRZ.)
This 26-year-old man was involved in a motorcycle accident, sustaining bilateral pneumothoraces, a fractured sternum and ribs, and a brachial plexus injury. He presented 2 years after the injury and was thought to be a good candidate for reestablishment of elbow function with an innervated gracilis transfer motored by the third, fourth, and fifth intercostal nerves.

Fig. 12C-12  A, The gracilis muscle dissected and ready for transfer. Maximal length was obtained when dissecting the obturator nerve. The full length of the distal tendon was also harvested to allow secure flap inset. B, The flap has been partially inset with anchor sutures to the acromion. The medial femoral circumflex artery was anastomosed to the brachial artery in end-to-side fashion while venous anastomoses were performed to the cephalic and comitans veins. It is always a good idea to harvest a skin paddle in these cases as one tends to underestimate the skin requirement for placement of the muscle graft. If the skin paddle is not needed, it can be discarded during closure. C, After flap inset. The extra skin has allowed tension-free closure. The distal gracilis tendon was secured to the biceps tendon with the muscle at proper length, compared with its length at the donor site. The skin paddle can be removed serially later, after the patient has completed rehabilitation. (Case supplied by MRZ.)
This 54-year-old woman had undergone bilateral mastectomy for a left breast cancer 2 years earlier. She received postoperative chest irradiation on the left. She opted for delayed reconstruction; she wanted to regain her B cup breasts and was not interested in breast implants. Although patients may sometimes wish to have small breasts reconstructed, it is technically difficult to shape them, especially in bilateral cases, with standard TRAM techniques. The TUG flap is a perfect choice in these situations, because it is available, has similar morbidity to a medial thigh lift with its benefits, and is actually easier to shape into a small breast.

**Fig. 12C-13**  
**A**, Preoperative view. Bilateral DIEP reconstruction was offered to the patient, because it was thought that she had adequate tissue for small breast reconstruction. She preferred not to have an abdominal flap transfer.  
**B**, Intraoperative view with the patient supine and frog-legged. This allows access for harvest and closure and still allows the surgeon to sit the patient upright for inset and shaping. The anterior extensions of the flap were for dog-ear control only, because they are poorly vascularized in this flap.  
**C**, The flap after harvest. The elliptical design of the flap folds into a natural cone, with the narrow base necessary for a small breast. The flaps were anastomosed to the mammary system.  
**D**, The patient is seen 8 months postoperatively. The patient did not want nipple reconstruction because she enjoyed not wearing bras, so a three-dimensional tattoo was created. No revisions of the breasts or thighs were required.  
**E**, Donor site. The patient appreciated the benefits of the thigh lift as well as the reconstruction. (Case supplied by MRZ.)
This 19-year-old had an Achilles tendon rupture and developed a wound infection after repair. An Achilles tendon reconstruction with gracilis muscle and tendon was planned.

**Fig. 12C-14**  
A, There was loss of the distal Achilles tendon with complete disruption, and the patient was unable to plantar flex with the calf muscles.  
B, A gracilis muscle was harvested through an 8 cm proximal incision and small counterincision at the knee. The proximal end was sutured into the space between the gastrocnemius and soleus muscles.  
C, The distal tendon was folded over on the muscle itself into a “hot dog in a bun” pattern to shorten the muscle tendon unit and still keep the tendon. The distal end was stretched out and repaired directly to the calcaneus.  
D, The entire muscle was skin grafted.  
E-G, One year postoperatively, the patient has excellent plantar flexion and is able to hop on one foot. (Case courtesy Rudolf F. Buntic, MD.)
In an automobile rollover accident, this 58-year-old woman sustained a devastating crush injury to her forearm with loss of flexor muscles. Forearm reconstruction was planned with a functional TUG flap.

**Fig. 12C-15**  
A and B, The patient is seen immediately after injury. C, In a first stage, the wound was covered with a latissimus muscle and skin graft. She had no active finger flexion. D and E, In a second stage, a TUG flap with a transverse skin paddle was used for functional reconstruction of the flexors of all five fingers. F, The TUG skin paddle was rotated 90 degrees to longitudinally cover the muscle.  
G and H, Two years postoperatively, the patient is able to flex her fingers enough to hold a hair dryer and use the hand as an assist for activities of daily living. (Case courtesy Rudolf F. Buntic, MD.)
Resection of an acoustic neuroma resulted in complete right facial paralysis in this 58-year-old woman. Facial reanimation with a thinned gracilis flap was planned.

**Fig. 12C-16**  
A, The patient is seen preoperatively with complete right facial paralysis. B, A gracilis muscle was harvested from the contralateral thigh and C, was thinned to retain the posterior aspect of the muscle and D, to increase nerve length. The final flap measured 11 by 3 cm. E, A single-stage facial reanimation procedure was performed by coapting the gracilis muscle to two contralateral facial nerve branches. F, One year postoperatively, she has excellent pull on her smile. (Case courtesy Rudolf F. Buntic, MD.)
This 40-year-old man presented with an anterior compartment loss after a compartment syndrome and debridement of anterior compartment muscles. A lower extremity anterior compartment reconstruction with a functional gracilis muscle was planned.

Fig. 12C-17  A and B, The patient is seen preoperatively. As a result of his injuries, he had no dorsiflexion of the foot. C, Flap design. D, A contralateral gracilis muscle was used for anterior compartment reconstruction. E, An external fixator was placed first to maintain the foot in the dorsiflexed position and to maintain muscle tension in the postoperative period. The muscle was inset proximally to the tibial condyle and distally to the tibialis anterior tendon in a Pulvertaft weave. F and G, At 9 months postoperatively, the patient is able to dorsiflex to near-neutral and can walk without an ankle-foot orthotic. (Case courtesy Rudolf F. Buntic, MD.)
This child had a congenital unilateral right facial paralysis. It really had not changed significantly since birth. Fortunately, she did not have any functional issues related to eye closure or mouth closure. However, she was very shy and embarrassed about her facial asymmetry, particularly with smiling or laughing. We discussed microsurgical reconstruction with a two-stage approach. She underwent a cross-face nerve graft whereby facial nerve branches on the normal left side were identified. An appropriate branch was selected for nerve grafting, and we determined that other branches were present to preserve the innervations of the normal side. One year after the cross-face nerve graft was carried out, a second procedure was done in which a segment of the gracilis muscle was transplanted to the face. It was appropriately positioned so that the origin and insertion would replicate the normal side as much as possible. The muscle was revascularized through the facial vessels and reinnervated using the previously placed cross-face nerve graft.

Fig. 12C-18  A, Preoperative view at rest; note the mild right commissure droop. B, Following the second procedure, the patient is seen at rest; note that the position of commissure has been elevated to match normal side. C, Preoperative view with smile; note the lack of closure of the right eye, as well as minimal commissure movement. D, Postoperatively, the patient when smiling demonstrates good excursion and fairly symmetrical nasolabial crease formation. The smile on the right side is spontaneous; the transplanted muscle is innervated by the normal side facial nerve with the aid of a sural nerve graft extension. (Case courtesy Ronald M. Zuker, MD.)
This boy had an untreated severe clubfoot deformity. To correct the deformity, an open osteotomy was carried out to the midfoot. The Achilles tendon was also released and lengthened. This left a complex defect with an exposed bone and joint, as well as an exposed, uncovered Achilles tendon. The gracilis muscle was used to cover the irregular complex defect in the midfoot. The proximal portion was split so that it would wrap around the Achilles tendon.

Fig. 12C-19  A-C, Preoperative appearance of the patient's neglected clubfoot deformity.
One portion went on the superficial aspect and one portion on the deep aspect between the tendon and calcaneus. The muscle was revascularized through an end-to-side anastomosis with the posterior tibial artery and an end-to-end anastomosis to the posterior tibial vein. The muscle was inset also beneath the margin of the adjacent skin. The surface was covered with a split-thickness skin graft.

Fig. 12C-19  D, Surgical defect after midfoot osteotomies and bony repositioning. E, Intraoperative appearance with the gracilis muscle in place filling the midfoot defect and encompassing the Achilles muscle. F and G, Postoperative appearance after complete, satisfactory wound healing. Excellent positioning of the foot was maintained, and an adequate range of motion of the ankle was preserved. (Case courtesy Ronald M. Zuker, MD.)
This boy was born with Moebius syndrome; thus he had bilateral and virtually complete paralysis of his sixth and seventh nerves. He also has partial twelfth nerve involvement and bilateral clubfeet. His development had been quite normal, and he was participating in normal activities. However, his main complaint was that he had no facial expression. He was unable to communicate his emotions with his face, and this was affecting his psychosocial integration. In addition, he also had some difficulty with bilabial sounds such as “P” and “B,” because he was unable to elevate his lower lip to his upper lip. His fifth nerve function was normal, and our plan was to carry out segmental gracilis muscle transplantations, which would be revascularized by the facial vessels and reinnervated with the motor nerve to the masseter muscle. Each side was done separately, about 6 months apart.

Fig. 12C-20 A, Preoperative appearance. B, The patient attempting a smile. C, Intraoperative appearance of the segmental gracilis muscle transplant demonstrating origin and insertion, as well as the site of vascular anastomoses and motor nerve repair.
Pearls and Pitfalls

- Positive identification of the gracilis muscle is vital; it is difficult to identify in some patients, especially obese individuals.
- Identification of the tendon distally and definitive identification of the obturator nerve and the medial circumflex femoral pedicle proximally are critical.
- The distal third of the leg should not be included in the design of the myocutaneous gracilis flap, because it is unreliable.
- The vascular pedicle has a small-diameter artery—sometimes less than 1 mm at its origin.
- Although it is tempting to sometimes shorten the harvest time by not fully dissecting the pedicle, it is essential in microvascular transfer to dissect the pedicle to its profunda femoris source for the best possible arterial diameter and vessel match to the recipient site.
- On occasion, the arc of rotation of the flap does not allow the muscle to adequately reach the reconstruction site. Division of the medial circumflex femoral pedicle should be considered, because the muscle flap may receive adequate vascularity from smaller vessels present around its origin.
- Transverse skin paddle designs put the patient at risk for lymphedema. Care should be taken in harvesting these flaps to avoid deep dissections around the femoral triangle.
EXPERT COMMENTARY

Rudolf F. Buntic

Indications
The length and reliable vascular pedicle of the gracilis and its potential as a myocutaneous flap make the gracilis flap a workhorse of reconstructive surgery. Local wounds from the groin to the perineum can be reached, while ischial pressure sore dead space can be obliterated from a posterior thigh approach. Distant reconstructions from head to toe, depending on recipient site needs, may all be candidates for this flap. It is an excellent choice in facial reanimation or for extensor or flexor reconstruction of the forearm. I consider the gracilis to be the preferential functional muscle donor when great power is not needed, and the preferred flap any time small defects in and around the distal third of the lower extremity require coverage of vital structures.

Advantages and Limitations
The foremost advantage of the gracilis flap is the extremely consistent pedicle and nerve that can be harvested with a patient in the supine position. The primary blood supply and innervation of the muscle show little variability, in contrast to a perforator flap, and anatomic variants of any significance are few. This helps to make harvest of the gracilis easy and rapid. The length of the muscle provides excellent excursion, allowing reconstruction of defects of extrinsic muscles of the hand and wrist and the anterior compartment of the lower leg. Finally, the large tendon at the distal aspect of the muscle offers a significant advantage over other functional muscle transplants. This allows direct repair to forearm and foot tendons with strong weaves or locking looped sutures.

The long, thin nature of the gracilis does have some drawbacks. Wide defects are not amenable to coverage. Two-bone forearm coverage or large lower extremity defects are often best served by a latissimus muscle or other flap with a larger surface area. The power generated by the gracilis muscle precludes its use for reconstructing foot flexion and knee extension, where more power is needed. The power generated by muscle contraction is proportional to the cross-sectional area of the muscle body.

In a heavier patient, the thick inner thigh fat of the gracilis skin paddle does not make a good side-to-side match with the forearm or lower leg skin and subcutaneous tissue.

Anatomic Considerations
1. The muscle can be slipped under the adductor longus to be pedicled laterally (see Fig. 12C-5).
2. There are valves immediately at junction of the gracilis veins and the profunda femoris vein resulting in veins that are usually a centimeter shorter than the artery.
3. The nerve splits into three branches as it enters the muscle, providing separate motor supplies to the anterior, middle and posterior aspect of the muscle. This can be mapped intraoperatively with a nerve stimulator and must be taken into consideration when thinning the muscle (see Fig. 12C-16).
4. The tendon can sometimes be quite thin and is very distal on the flap (see Fig. 12C-2).

When attempting to do a Pulvertaft weave to lower or upper extremity tendons, the surgeon immediately encounters the body of the muscle of the gracilis shortly after pulling the tendon through the weave, limiting the passes of the weave and ability to tighten the muscle at the distal point.
**Personal Experience and Insights**

Although the harvest of the gracilis is simple, inset for upper and lower extremity functional reconstruction is challenging and requires planning. The recipient area artery and veins may not be adjacent to the nerve that will provide motor innervation to the muscle. Nerve grafting should be avoided to minimize time to muscle innervation. If the nerve is positioned well, the vessels may end up kinked to support the lie of the nerve. Likewise, if the vessels and nerves are perfectly repaired with a good lie, further inset of the muscle and stretching it back out to length may result in kinking or placing tension on microsurgical repairs. It is better to consider where the nerve and vessels will lie ahead of time and then inset the proximal and distal muscles, completing the inset of the muscle before vessel and nerve repairs if possible, but still allowing access to the repair sites.

In functional muscle reconstruction of the forearm, the proximal gracilis needs to be repaired above the elbow in order to achieve tendon repair in the distal wrist. Two functions for one muscle. For flexor repair, the tendon can be split distally for weave to the thumb and fingers in separate weaves.

For facial reanimation, great strength is not required for a smile, and the muscle can be thinned significantly. Segmental innervation patterns should be defined with a nerve stimulator and thinning done between innervations territories.

The proximal gracilis tendon is very short and must be taken right of the ischial origin if a functional muscle is being used. The proximal tendon is needed to secure the new muscle origin in the recipient site.

**Recommendations**

**Planning**

In functional reconstruction, the proximal gracilis will need to be inserted above the elbow, and in the leg, at the tibial condyles. This brings the ulnar nerve into play in the forearm and the peroneal nerve into play in the leg. Compression of these nerves must be avoided. The muscle should be marked at 5 cm intervals with thin Prolene sutures before proximal or distal transection in the thigh. This allows placement of the muscle on appropriate tension in the recipient area when performing functional muscle transplants. The surgeon should avoid obstructing exposure to the vessel and nerve repair, or kinking or tugging on the vessel and nerve repair with the inset of the muscle.

**Technique**

Self-retaining retractors are used distal and proximal to the pedicle to widely retract the adductor longus and magnus muscles. These retractors should be adjusted as needed to maintain good exposure while dissecting the pedicle to the origin. One must be watchful not to impale the nerve with the self-retaining retractors if the nerve is to be used.

If the patient is large or obese, the adductor longus muscle can be retracted medially, and the pedicle of the gracilis can be dissected to its origin between the longus and vastus medialis. This allows easier dissection of the root of the pedicle and a more direct lie of the pedicle when covering groin structures.

The proximal tendon is very short and can shred easily with suturing. If needed, maximal length should be obtained by removing it directly from the origin of the ischium with good exposure and retraction to this area.

*Continued*
Postoperative Care
Postoperative care of a patient with a gracilis flap reconstruction is generally uncomplicated, except in the TUG flap. The large potential space requires drains to be secured well into position and left in place much longer than for typical gracilis flaps. Seroma formation is common in the TUG flap, but rare in muscle-only harvest.

Complications: Avoidance and Treatment
Seroma formation can be quite a nuisance. If drains are removed too early, surgical excision of the seroma cavity with reclosure and drainage may be needed if the patient feels bulging pressure in the inner thigh.

It is easy to injure the small veins of the pedicle, where branches to the adductor longus and magnus are present. These very small branches are handled by good retraction and micro hemoclips or bipolar cautery. Countertraction is the key to exposure of the pedicle and its branches.

Take-Away Messages
The gracilis is a workhorse flap. Along with the latissimus, ALT, fibula, and radial forearm flaps, knowledge of this flap is a must for every reconstructive surgeon. The gracilis is a go-to flap for many defects. The simple anatomy and ease of harvest allow the surgeon to concentrate on the reconstruction.

EXPERT COMMENTARY
Ronald M. Zuker

Indications
The gracilis flap has a very broad application in reconstructive surgery. It can be used for vascularized cover in very complex wounds, either through regional rotation or free tissue transfer. It is particularly useful for coverage of small areas in poorly vascularized regions, such as the lower extremity or in an irradiated bed. Its most dramatic use, however, is as a functioning muscle, whereby it is not only revascularized but also reinnervated with a motor nerve for function. This has found broad application in the upper extremities and in the face. In the upper extremities, it has been used for finger flexion, finger extension, deltoid replacement, and biceps replacement. In the face, it is a major workhorse for muscle transplantation for the treatment of facial paralysis to replicate the actions of the zygomaticus major, zygomaticus minor, and levator labii muscles. Much of this commentary will be related to its use in facial paralysis reconstruction.

Advantages and Limitations
The gracilis muscle has a superb neurovascular anatomy that facilitates free tissue transfer. In particular, the single motor nerve is most helpful for functioning muscle transplantation. The gracilis muscle can be harvested at the same time as recipient site dissections in the upper extremity or in the face, facilitating a simultaneous two-team approach. The anatomy is consistent and reliable, and the flap relatively easy to dissect. The muscle can also be reduced in size, both lengthwise and widthwise, to suit the purpose for which it is being applied. Last, but by no means least, the donor site leaves no functional deficit, even when the entire gracilis is harvested. The scar is relatively well hidden in the upper inner thigh, although it does often spread.
The flap’s limitations are primarily related to its size. It is too long for easy use in the upper extremity and often needs to be shortened. Similarly, in the face, the origin and insertion are often in the muscular component rather than a fascial component. This makes anchorage complex. It is important to avoid the pulling through of the muscle, which would thereby disconnect it from its site of origin or insertion. Last, the gracilis muscle is too bulky for use in the face unless it is carefully tailored. This often involves reducing the diameter by a half or two thirds to avoid excess bulk. Care must be taken in the face to avoid placing the muscle over bony prominences, such as the malar prominence. To avoid excess bulk in the temple region, the muscle can be spread out over the origin in the temple.

**Anatomic Considerations**

The anatomy of the gracilis is quite consistent and well described in the chapter. I find identification of the myocutaneous perforator vessel a great aid in locating the pedicle. When the perforator is found, the pedicle is directly beneath it on the deep surface of the muscle.

**Personal Experience and Insights**

The gracilis muscle has been the workhorse for us in functioning muscle transplantation to the upper extremity and to the face. The anatomy is consistent, and I have never had to switch to the other side because of aberrant anatomy. I have had experience with vascular anomalies whereby a portion of the adductor had to be used, and this was quite feasible. One should always be watchful for anatomic variations, but in my experience the gracilis is extremely consistent.

**Recommendations**

**Planning**

It is essential to have a precise plan for reconstruction. The size of the defect must be smaller than the planned flap. For wound coverage, overlapping the muscle beneath the adjacent skin around the entire defect is very helpful. It adds a further layer of security, should there be a minor dehiscence at one edge of the repair. In the face, it is important to reduce the size of the muscle to avoid excess bulk. For facial paralysis reconstruction, an accurate and secure origin and insertion are critical. The muscle also must be powered by an appropriate motor nerve. This can be the ipsilateral facial nerve or the contralateral facial nerve via a cross-face nerve graft or a regional motor nerve, such as the motor nerve to masseter. A more powerful input will lead to a more powerful contraction and greater excursion. It is also important to place the muscle at the appropriate tension, so that when contraction occurs it will be most effective. In facial paralysis reconstruction, it is best to elevate the drooping oral commissure so that it is even with the normal side and under a slight amount of tension. Thus, when innervation does occur, it will lead to muscle contraction that will immediately move the oral commissure.

**Technique**

The technical details regarding facial reanimation are extremely important. The four key elements are appropriate and secure muscle fixation, reduction of excess bulk, provision of a strong motor input, and placing the muscle under appropriate tension.

**Postoperative Care**

Wound closure of the gracilis donor site is usually straightforward. I generally do not use drains and close the wound in layers with absorbable sutures, subcuticular sutures for the skin and reinforced with glue. A circumferential support dressing is also used for the first
2 days. In wound closure, it is important to close the deep fascia. I have had instances of muscle herniation, which does not pose a functional problem, but is aesthetically concerning. With careful closure of the deep fascia, this can be avoided.

Complications
The complications associated with the gracilis donor site include infection, hematoma, and seroma. I now make a rule of thoroughly irrigating the wound with saline solution before closing the wound, because it may have been open for several hours, and wound closure may not take place until the recipient site has been effectively completed. Perioperative antibiotics are also used, and with these two measures, our infection rate has been controlled.

Take-Away Messages
I have found the gracilis flap to be anatomically consistent and extremely useful and versatile, with broad application. It can be used for vascularized cover as well as function in both the upper extremities and the face.

EXPERT COMMENTARY
Michael R. Zenn

Indications
The gracilis flap is one of the few basic reconstructive flaps that all plastic surgeons need to master in a successful practice. The reason lies in its versatility and low morbidity. Its uses run the gamut from decubiti and wound closure to functional muscle transfer and free flap breast reconstruction.

Anatomic Considerations
Anatomically the gracilis muscle is ideal, since it has a reliable and sizable vascular pedicle that is not critical for vascularizing the leg. It has a single large motor nerve that supplies no other muscles. The muscle can be spread out to cover a large area or pared down when the smallest possible innervated muscle is required. Its pedicle location is favorable for rotation when used on the most difficult problems of the perineal and groin areas, such as fistulas, exposed vascular grafts, and issues leading to anal incontinence.

Advantages and Limitations
The general location of the upper thigh is also a plus in that it affords two-team approaches to reconstructive problems in the head and neck, upper extremity, and lower extremity. Its donor scar along the inner thigh is inconspicuous and well tolerated by most patients. In a transverse design (TUG flap), the scar is identical to the scar found in medial thigh lifts, a cosmetic procedure.

With all of those strengths, there are a few important things to remember to successfully use this flap in reconstruction. First, identification of the muscle is key as an initial step. More than a few sartorius and adductor longus muscles have been completely skeletonized before the misidentification has been realized. Second, one should not rely too much on the distal 25% of the muscle for bulk. Some patients will have mainly tendon in the terminal portion, and that could be a big issue if muscle bulk is needed, as in repair of a fistula or coverage of a vascular graft.
In fact, if the surgeon is mere centimeters away from a successful reconstruction and needs just a little more length, there are two maneuvers to keep in mind. First, the medial femoral circumflex pedicle should be dissected completely to the profunda femoris, dividing all side branches. This will generate an extra 1 or 2 cm. When that is still not enough, the medial femoral circumflex pedicle can be divided. If the proximal portion of the muscle has not been skeletonized, the blood supply from around the bony origin may be enough to carry the flap. Having read about it, I have only found myself in that situation once, and it worked like a charm. I would not recommend it routinely, and in my case, the muscle was useless for the reconstruction if it did not reach.

Complications: Avoidance and Treatment

The last word to remember about the gracilis flap is seroma. The area has plenty of lymphatics and is a highly mobile area in an ambulatory patient. Drains should remain in place longer than for other reconstructed sites, and seromas must be managed aggressively and early to avoid the dreaded replacement of a drain. The corollary to seroma is lymphedema. I have seen gracilis patients and medial thigh lift patients with problematic lymphedema. The surgeon must respect the lymphatics of the groin and avoid deep and skeletonizing dissection around the femoral system.

Bibliography With Key Annotations


The authors described the use of a free innervated gracilis muscle flap for functional thenar reconstruction in two unique cases following extensive traumatic loss of thenar skin and musculature. Crucially, in each case, the recurrent motor branch of the median nerve had been destroyed at its point of insertion into the thenar muscle remnants. To date, the main reported disadvantages of free functioning muscle transfer in thenar reconstruction include difficult flap dissections, donor site morbidity, inadequate strength and excursion of the transplanted muscle and excessively bulky flaps. Their aim was to address these issues. Each thenar defect was measured and a corresponding segment of gracilis muscle, measured in situ, was raised on the proximal neurovascular pedicle. End-side microvascular anastomosis was performed between the medial circumflex femoral artery and the radial artery. The venae comitantes of the pedicle were anastomosed end-to-end with those of the radial artery and also with the cephalic vein. Epineural anastomosis was performed between the motor branch of the obturator nerve and the recurrent motor branch of the median nerve. Each flap was covered with a split-thickness skin graft. Both flaps survived without any complications. Both patients regained excellent voluntary thumb opposition, sufficient to allow return to full-time employment, and had restoration of sufficient thenar bulk. This was achieved with minimal donor site morbidity.


Reconstruction of complex urethral defects should provide lasting coverage, a patent tube for voiding, and a natural appearing contour with minimal morbidity to the donor and recipient sites. Many reports have emerged in the literature regarding complex urethral reconstruction through a variety of methods including anterolateral thigh flaps, radial artery forearm free flap, and other simple skin and mucosal flaps. Recently, Ozkan and Ozkan reported using a prefabricated anterolateral thigh flap for reconstruction of a traumatic urethral defect. In this report, the authors described their experience with the
use of a prefabricated gracilis muscle flap in a female-to-male transsexual with a complex proximal urethral stricture and distal fistula. The authors stated this was the first report of a prefabricated gracilis myocutaneous muscle flap being used for a long segment urethral stricture and distal fistula. The authors noted that this procedure offers a unique solution to a difficult problem with decreased morbidity and cosmetic advantages over other methods requiring microvascular anastomoses.


The gracilis muscle has been used extensively in reconstructive surgery, based on the proximal dominant pedicle, but little attention has been paid to the secondary distal pedicles. The authors investigated distribution of the secondary pedicles of the gracilis muscle in 20 cadaver thighs. The mean number of secondary pedicles was 2.2. When two pedicles were present, the most common situation, they were located at a mean distance of 12.4 and 17.5 cm from the knee joint line. The most proximal secondary pedicle was injected with barium sulfate in five specimens, and constant and abundant connections with the main pedicle were noted. A series of seven clinical cases of segmental gracilis free muscle flaps based on a secondary pedicle was reported. The flaps were successfully transferred to reconstruct traumatic defects of limited size, with one case of partial necrosis caused by a technical error. The morbidity of this flap is minimal, the scar is well hidden, the muscle need not be sacrificed, elevation is fast and straightforward under tourniquet control, and the pedicle was sizable. This flap should be considered a viable option when a small, straightforward free flap is needed.


Long-standing facial paralysis requires the introduction of viable, innervated dynamic muscle to restore facial movement. The options include regional muscle transfer and microvascular free tissue transfer. There are advantages and disadvantages of each. Briefly, the regional muscle transfer procedures are reliable and provide immediate return of movement. However, the movement is not of a spontaneous mimetic nature. Free tissue transfer, in contrast, offers the possibility of synchronous, mimetic movement. However, it does require a prolonged healing time in comparison with that of regional muscle transfer. The choice is made by the physician and patient together, taking into account their preferences and biases. Muscle-alone free tissue transfer is the author’s preferred option for reanimation of uncomplicated facial paralysis without skin or soft tissue deficits. Combined muscle and other tissue (most are skin flap) is another preferred option for more challenging complex facial paralysis with skin or soft tissue deficits after tumor excision. Gracilis flap is the author’s first choice of muscle transplantation for both reconstructions.


Gracilis functioning free muscle transplantation for the correction of pure facial paralysis has been a preferred method used by many reconstructive microsurgeons. However, for complex facial paralysis, the deficits include facial paralysis and defects of the soft tissue, mucosa, and/or skin. No adequate solution has been proposed. Treatment requests in such patients are not only for facial reanimation but also for correction of the defects. Of 161 patients with facial paralysis treated with gracilis functioning free muscle transplantation from 1986 to 2002, eight patients (5%) presented with complex deficits requiring not only facial reanimation but also aesthetic correction of tissue defects. The tissue defects included an intraoral defect created following contracture release (one patient), infraauricular radiation dermatitis with contour depression (one patient), temporal depression following a temporalis muscle—
fascia transfer (one patient), ear deformity (two patients), and infraauricular atrophic tissue with contour depression (three patients). A compound flap consisting of a gracilis muscle with its overlying skin paddle separated into two components was transferred for simultaneous correction of both problems. The blood supply to the gracilis and to the skin paddle originated from the same source vessel and therefore required the anastomosis of only one set of vessels. The versatility of this compound flap allows for a wide arc of rotation of the skin paddle around the muscle. All flaps were transferred successfully without complications. Satisfactory results of facial reanimation were recorded in five patients after all stages were completed. The remaining three patients were undergoing physical therapy and waiting for revision of the skin paddle.


Although multiple flaps have been used for vaginal reconstruction, a logical approach to reconstruction of these often complex defects has not been described. The objective of this study was to establish a classification system for acquired vaginal defects and to develop a reconstructive algorithm derived from this system. The authors presented a classification system: partial defects involving the anterior or lateral vaginal wall were classified as type I A defects and were reconstructed primarily with pedicled Singapore fasciocutaneous flaps. Partial defects involving the posterior wall were classified as type IB and were reconstructed with pedicled rectus abdominis myocutaneous flaps. Circumferential defects involving the upper two thirds of the vagina were classified as type IIA defects and were reconstructed with a rolled rectus flap or, less commonly, sigmoid colon (one patient). Total circumferential defects, type IIB, were reconstructed largely with bilateral gracilis flaps. Flap selection is determined on the basis of the type of defect. Using this algorithm, immediate vaginal reconstruction with pedicled regional flaps can be performed with minimal patient morbidity and few surgical complications.


Scrotal skin has unique cosmetic and functional features that make its reconstruction difficult. Coverage of the testicles and producing a good cosmetic appearance are major expectations from a successful reconstruction. Usually flaps are the choice for scrotal reconstruction, but every single flap has its own characteristics. In their series, between January 2006 and January 2010, the authors used the medial circumflex femoral artery perforator flap in seven male patients for scrotal coverage after Fournier gangrene. Six flaps were raised based on a single perforator from the gracilis muscle; in one flap two perforators were used. Flaps were carried to the defect either by transposition or by V-Y advancement. Donor areas were closed directly in all patients, and stable scrotal coverage was achieved with an acceptable scrotal contour and cosmesis. No major complication occurred as a result of the perforator flap surgery; in two patients wound dehiscences were noted and they healed by secondary intention or by secondary suturing. For scrotal reconstruction, the medial circumflex femoral artery perforator flap is a good option with its good mobility, thinness for scrotal contour, possibility for muscle preservation, and direct closure of the donor site. All these advantages can be accomplished in one procedure.


Microvascular free flaps continue to revolutionize coverage options in head and neck reconstruction. The authors described their experience with the gracilis free flap and the myocutaneous gracilis free flap for reconstruction of head and neck defects. Eleven patients underwent 12 free tissue transfer to the head and neck region. The reconstruction was performed with the transverse myocutaneous gracilis (TMG) flap (7) and the gracilis muscle flap with skin graft (5). Total flap survival was 100%. There were no partial flap losses. Primary wound healing occurred in all cases. Recipient site morbidities included one hematoma. In their experience for reconstruction of moderate volume and surface area defects, muscle flaps with skin graft provide a better color match and skin texture relative to myocutaneous or
fasciocutaneous flaps. The gracilis muscle free flap is not widely used for head and neck reconstruction but has the potential to give good results. As a filling substance for large cavities, the transverse myocutaneous gracilis flap has many advantages, including reliable vascular anatomy, relatively great plasticity, and a concealed donor area.


The authors reviewed the applications of the extended-dissection technique of the gracilis flap in a high-risk patient population with complex wounds requiring more coverage than a standard gracilis flap may provide. To their knowledge, this was the first study applying the extended-dissection technique as described by Hasen et al to pedicled gracilis flaps. They conducted a chart review and identified 19 consecutive patients as having undergone an extended gracilis dissection. Once the pedicle is identified on the medial border of the gracilis, dissection continues proximally, dividing the rich vascular network of perforators to the adductor muscles. The gracilis is then passed beneath the adductor longus and delivered adjacent to the sartorius, where dissection proceeds directly down to the profunda femoris. All reconstructions were successful. There was one complication presenting as a late infection at the donor site. Mean patient age was 66 years, and nearly all patients had multiple significant comorbidities, including diabetes, peripheral vascular disease, and/or radiation therapy. The extended-dissection technique for gracilis harvest has significant benefits for use in pedicled flaps, including a greater arc of rotation and no restriction on postoperative ambulation or thigh abduction. These factors are particularly important in the challenging patient population represented in this study and add to the reliability and versatility of the gracilis flap.


The upper medial thigh perforator flap is a free-style skin flap elevated suprafascially from the upper medial thigh in a transverse manner based on any reliable perforator. A total of 40 cases were performed in 40 patients with lower extremity soft tissue defects from various causes. The anatomy of the flap, elevation technique, and results after reconstruction were evaluated. An average number of 1.3 reliable pulsating pedicles was noted entering the flap; 90% originated from the medial circumflex femoral artery. The perforators were one third myocutaneous and two thirds septocutaneous type. The average length of the pedicle was 6 cm; the average diameter of the artery was 0.8 mm. The flaps were thinned according to the needs of the patient. The donor sites were closed primarily. Thirty-nine flaps survived, and no recurrence of the original abnormality was seen during the follow-up period. Despite the short pedicle length, small diameter of the vessel, and inconsistent perforator position, the surgeon can use the upper medial thigh perforator flap to overcome the disadvantages by understanding the free-style free flap approach. The flap can obtain reasonable size, well-hidden scar, preservation of muscle function, good pliability, and superficial nerves and vein included for additional quality. This flap, in the hands of experienced surgeons, can be reliable for reconstructing the lower extremity.


Autologous breast reconstruction is predominantly performed using free transverse rectus abdominis myocutaneous or deep inferior epigastric perforator flaps. However, some patients are not suitable candidates for flaps from the lower abdomen. The transverse skin island of the gracilis muscle presents an additional option, as it includes tissue from the posterior upper thigh/lower buttock and thus delivers the amount of tissue necessary for breast reconstruction. In 2007, the authors’ unit performed 73 free flaps for breast reconstruction subsequent to carcinoma, implant-related capsular fibrosis, and breast asymmetry. The transverse myocutaneous gracilis flap was used 32 times in 20 patients. The ventral margin was the greater saphenous vein, and the posterior margin was the midline of the inferior gluteal fold. The skin island could be harvested to a width of up to 30 cm and a height of up to 10 cm. The
donor site was closed primarily. Mean follow-up was 6 months. Mean operating time was 220 minutes for unilateral and 325 minutes for bilateral cases. All flaps and donor sites healed uneventfully. An initially described “tight feeling” at the thigh ceased after 2 to 3 weeks. Persistent hypesthesia of the dorsal thigh was not noted. A major asymmetry of the thigh in unilateral transplantations was not apparent. After 6 months, all flaps were soft. The transverse myocutaneous gracilis flap is a safe, fast flap for reconstruction after benign and malignant breast disease. It combines a constant vascular pedicle with soft subcutaneous tissue that has breastlike characteristics.


Autologous free tissue transfer is an ideal method for breast reconstruction. The deep inferior epigastric perforator (DIEP) flap is considered the gold standard procedure worldwide. However, in selected patients this flap cannot be performed to achieve satisfactory outcomes. The transverse myocutaneous gracilis (TMG) flap is one of the most recent additions to the armamentarium of breast-reconstructive surgeons. This flap can provide adequate autologous tissue with a hidden scar. The authors noted that since its description for breast reconstruction in 2004, no series had been published, and its recognition was still lacking. The main criticism of this flap was the lack of volume that can be achieved and the potential for donor morbidity. The authors reported on a 2-year experience with the use of TMG flaps for breast reconstruction, assessing the potential indications and introducing some technical refinements to expand the role of this flap in breast reconstruction. Nineteen TMG flaps were performed in 12 patients (seven double procedures: five bilateral cases and two stacked flaps for unilateral breast reconstruction). One flap was lost 9 days postoperatively. Follow-up ranged from 6 months to 2 years. The authors detailed their surgical technique and described refinements to speed up flap harvest, increase flap volume, optimize flap inset and minimize donor site complications.

Hallock GG. The conjoint medial circumflex femoral perforator and gracilis muscle free flap. Plast Reconstr Surg 113:339–346, 2004. This perforator flap could be considered an ideal skin flap, because the defined skin territory is reliable, harvesting can be performed with the patient supine, and the vascular pedicle has a consistent location well known to plastic surgeons. Donor site scars in the medial groin can be readily concealed.

Hallock GG. Further experience with the medial circumflex femoral (gracilis) perforator free flap. J Reconstr Microsurg 20:115–122, 2004. The microsurgical transfer of the medial groin skin territory previously required this to be part of a transverse-oriented gracilis myocutaneous free flap. As the concept of muscle perforator flaps has evolved, avoidance of muscle bulk and/or retention of muscle function is also possible with the careful intramuscular dissection of the gracilis myocutaneous perforators back to the usual medial circumflex femoral source vessel. This so-called medial circumflex femoral (gracilis) perforator free flap has been successfully used seven times in six patients with minimal complications. The gracilis muscle perforator flap may well represent the ideal skin flap: no muscle function is sacrificed; a reliable skin territory of large size is available; the dominant vascular pedicle is consistent in location; the flap may be harvested with the patient in a supine position; a combined conjoint flap including the gracilis muscle is optional; closure of the donor site leaves a medial groin scar that can be readily concealed; and flap dissection in this region is already very familiar to most microsurgeons.

Hasen KV, Gallegos ML, Dumanian GA. Extended approach to the vascular pedicle of the gracilis muscle flap: anatomical and clinical study. Plast Reconstr Surg 111:2203–2208, 2003. Dissection of the proximal gracilis vascular pedicle proceeds in a dark tunnellike space deep to the adductor longus. With the application of a previously described technique for an extended approach to the lateral arm free flap, the authors described a novel technique that improves observation and thus facilitates dissection of the proximal gracilis vascular pedicle. A retrospective review of data for 18 consecutive patients who underwent gracilis muscle free flap harvesting with this modified technique...
in 2001 was conducted to assess flap viability and patient outcomes. A cadaveric dissection was also performed to study the anatomic features of the region in depth and to test the proposed flap modification. After the standard incision has been made, the dominant pedicle is exposed on the medial aspect of the gracilis muscle, running in a fascial cleft between the adductor longus and the adductor magnus. Intramuscular branches to the adductor longus are divided. A space is bluntly created anterior and lateral to the adductor longus by separating the fibrous connections to the surrounding adductor and sartorius muscles on both sides of the vascular pedicle. The gracilis muscle is then divided and passed deep to the adductor longus, into this space. With this new position, the final dissection of the pedicle can easily be performed. The confluence of the venae comitantes is frequently encountered, providing a larger-caliber single vein for microvascular anastomosis. The free flap survival rate was 100%. One minor complication of a seroma at the donor site was observed. One major complication of venous thrombosis was detected on postoperative day 3, with complete flap salvage. No other complications were noted. This technique is safe and permits direct approach to and excellent observation of the proximal aspect of the gracilis pedicle, without the need for headlights or deep retractors. An additional benefit is the frequent finding of a single larger vein from the merging of the venae comitantes close to the deep femoral vessels.


Microsurgical tissue transfer has constantly improved the therapeutic options for reconstruction in the head and neck region, but the ideal flap has yet to be found. The authors reported their experience with the free gracilis muscle flap in seven patients who underwent reconstruction in the head and neck region for a variety of indications. In all seven patients the transplanted muscle flaps healed well, with no flap loss. Postoperative complications consisted of skin graft loss in one patient requiring a second split-thickness skin graft. Donor site morbidity was minimal in all patients. For difficult reconstruction in the head and neck region, the free gracilis muscle flap offers a number of advantages, including reliable vascular anatomy, relatively great plasticity, and a concealed donor area. Thus this type of flap offers a valuable option whenever an aesthetically pleasing result is sought.


The management of groin wounds is a common and challenging problem. The authors examined the anatomic basis of the gracilis muscle with relation to this problem. Twelve cadaveric lower limbs were studied to examine both the extramuscular and intramuscular vasculature of the gracilis muscle. These underwent dissection and in three cases radiologic examination. The mean entry point of the dominant arterial pedicle was 9.4 cm; the mean length and width of the muscle was 38.4 cm and 6.2 cm, respectively. Each gracilis muscle was then mobilized between the adductor longus and adductor magnus muscles on its dominant pedicle and transposed into the femoral triangle. In each case, the gracilis muscle mobilized easily on its dominant pedicle to adequately cover the groin. The gracilis muscle is a reliable muscle flap with a consistent blood supply that can be transposed easily into the groin, based on its dominant pedicle, and offers adequate coverage of the femoral vessels.


The authors analyzed the proximal perforator vessels of the gracilis myocutaneous flap. Twenty-three cadaver legs preserved by the Thiel method were carefully dissected 24 hours after the proximal vascular pedicle was injected with red silicone. Nine additional cadaver legs were injected with ink to visualize the skin area supplied by the proximal perforators, clarified by a modified Spalteholz technique to demonstrate the anatomic course of the perforators. A considerable variation in numbers and location of the proximal cutaneous perforators was found. One to four perforators were seen within an area of 6 by 6 cm² at the entrance of the main pedicle into the proximal gracilis muscle. Their external diameter
ranged from 0.5 to 1.0 mm. The ink injections showed an oval angiosome with a mean surface of 88 cm² at the level of the proximal gracilis pedicle. The authors concluded from this anatomic study that a cutaneous flap based on the medial circumflex femoral gracilis perforators can be harvested by experienced hands, bearing in mind the unpredictable perforator anatomy.


The loss of elbow flexion is an uncommon but devastating consequence of injury to the upper limb and a complex problem to manage. The authors described their experience with free functioning gracilis muscle transfer (FFGMT) to the upper limb for elbow flexion. Thirty-three patients were followed after FFGMT for elbow flexion: 26 patients were male and 20 were children. Indications for FFGMT included obstetric brachial palsy (13) and adult brachial plexus injury (12), arthrogryposis (4), sarcoma, polio and radial dysplasia. Seventy percent (23) of patients had a successful outcome. Power comparable to the other side (M5) was recorded in two patients, 19 patients scored M4, and three scored M3. FFGMT in the obstetric brachial palsy group alone (13) was the most successful; all had a preoperative score of M2 or less, and postoperatively 12 (92%) achieved a score of M4 or greater. A greater increase in Medical Research Council grade for elbow flexion was achieved when intercostal nerves were transferred to innervate the gracilis flap (mean gain three points, SD 1.3), than ulnar fascicles (mean gain 1.75 points, SD 2.3). With a multidisciplinary team approach involving experienced surgeons, theater staff, and therapists, a significant, reproducible, and measurable improvement in elbow flexion can be achieved by FFGMT.


Many patients who present for autologous breast reconstruction are not suitable candidates for abdominal wall flaps, either because of previous abdominal surgery (most commonly a transverse rectus abdominis myocutaneous flap for prior breast reconstruction) or because of the lack of enough adipose tissue. Another donor site option is the medial thigh, which has more recently been recognized as a source of tissue for breast reconstruction. Prior reports have described the harvest of a gracilis myocutaneous flap through a transverse incision. The authors reported on 12 patients who underwent autologous breast reconstruction of 15 breasts with the longitudinal gracilis myocutaneous microvascular flap. The patients’ ages ranged from 41 to 60 years (average 48 years). In all patients the longitudinal gracilis flap was chosen because of a desire for autologous reconstruction and a lack of available abdominal wall tissue. Mean follow-up was 16.8 months (range 5 to 36 months). There was no microvascular thrombosis or free flap failure in this series. Donor sites were well tolerated by all patients. Three patients underwent suction-assisted lipectomy of five donor site areas to improve contour and/or symmetry. The longitudinal gracilis myocutaneous flap is a useful alternative for breast reconstruction in properly selected patients.


Oncologic resections in the head and neck can result in a variety of complex defects. Many free tissue transfers have been described for soft tissue reconstruction in this area. The pedicled, vertical gracilis myocutaneous flap has been well described for use in the perineum but is rarely used as a free tissue transfer because of the previously documented unreliability of the skin island. The objective of this study was to review a single author’s experience with reconstruction of complex head and neck defects using the vertically oriented free myocutaneous gracilis flap. A retrospective review of all head and neck reconstructions at a major cancer center from 2003 to 2006 was performed. Demographic, oncologic, and reconstructive data were retrieved from a prospectively maintained clinical database. Mean follow-up was 8 months (range 2 to 20 months). Total flap survival was 100%. There were no partial flap losses. Primary wound healing occurred in all cases. The vertically oriented free myocutaneous gracilis flap...

From 1996 to 2004, 19 patients with lower extremity injuries whose lesions exhibited composite soft tissue damage, with or without bone defects, and certain accompanying functional disabilities were allocated to study groups on the basis of impression, as follows: group I, open fracture IIIB (10); group II, neglected compartment syndromes (open IIIB (4) and open IIIC (1)); and group III, crush injuries (4). Free flap resurfacing was indicated for these lesions. Fifteen patients underwent free functioning muscle transfer; source muscles were the rectus femoris (3), rectus femoris with anterolateral thigh flap (5), and gracilis (for ankle dorsiflexion) (7). Two patients underwent composite rectus femoris and vascular iliac crest for ankle dorsiflexion and segmental tibial defect reconstruction. Two received rectus femoris muscle and anterolateral thigh flaps for posterior compartment defect and quadriceps defect reconstruction, individually. Two patients required reexploration; salvage was successful in only one, with below-knee amputation necessary in the other. Skin grafts were needed for partial skin paddle necrosis (3) or remaining skin defect (2). Functioning muscle reinnervation failed in four cases, with one individual undergoing ankle fusion, two people electing amputation with stiff ankles, and one person using an orthosis. In the sample population, range of motion varied and was related to the severity of injury and the extent of skin grafting on the distal myotendinous portion. Less function was exhibited in the compartment syndrome group (group II).


Despite the availability of a variety of flap reconstruction options, ischial pressure sores continue to be the most difficult pressure sores to treat. The authors described a successful surgical procedure for the coverage of ischial ulcers using a modified gracilis myofasciocutaneous flap. The authors enrolled 12 patients with ischial sores in a study. All patients underwent early aggressive surgical debridement, followed by surgical reconstruction with a modified gracilis myofasciocutaneous flap. Follow-up ranged from 13 to 86 months (mean 44 months). Overall, 11 of 12 (91.7%) of the flaps survived primarily. Partial flap necrosis occurred in one patient. Primary wound healing occurred without complications at both the donor and recipient sites in all cases. In one patient, grade 2 ischial pressure sores occurred 13 months after the operation. There was no recurrence in the other 11 patients. A modified gracilis myofasciocutaneous flap provides a good cover for ischial pressure sores. Because it is easy to use and produces favorable results, it can be used in the primary treatment for large and deep ischial pressure sores.


An anatomic study was initially undertaken to record the existence, consistency, and diameter of myocutaneous perforators emanating from the proximal third of the gracilis muscle to provide blood supply to the overlying fascia, subcutaneous fat, and skin. In a total of 20 clinical cases of gracilis muscle harvesting, the anatomic data were recorded during flap dissection. At least one myocutaneous perforator, consisting of one artery and two accompanying veins (vein caliber greater than 0.3 mm) was found in 95% of cases. The anatomic study was followed by successful use of the conjoint flap for reconstruction of long-standing facial palsy accompanied by a soft tissue defect of the cheek. In the first stage, cross-face nerve grafting was performed. In the second stage, free transfer of the conjoint flap, consisting of the proximal third of the gracilis muscle and the overlying subcutaneous fat, was performed to the face. The only connection between the two components of the conjoint flap was one...
myocutaneous perforator. When the flap was inset, the muscle was used for facial reanimation and partial obliteration of the soft tissue defect, while the subcutaneous fat was used to obliterate the rest of the defect. The technique ensures symmetry of the face, on both rest and animation, and obliteration of the cheek deformity.


The authors studied the ability of the masseter motor nerve–innervated microneurovascular muscle transfer to produce an effective smile in adult patients with bilateral and unilateral facial paralysis. The procedure consisted of a one-stage microneurovascular transfer of a portion of the gracilis muscle that is innervated with the masseter motor nerve. The muscle was inserted into the cheek and attached to the mouth to produce a smile. The outcomes assessed were the amount of movement of the transferred muscle; the aesthetic quality of the smile; the control, use, and spontaneity of the smile; and the functional effects on eating, drinking, and speech. The study included 27 patients aged 16 to 61 years who received 45 muscle transfers. All 45 muscle transfers developed movement; age did not affect the amount of movement. Ninety-six percent of patients were satisfied with their smile.


The gracilis muscle flap is certainly among the most versatile sources of vascularized tissue available for microsurgical reconstruction. However, the aesthetic appearance of the resultant scar has frequently been a source of dissatisfaction. Various minimal invasive techniques have been proposed, all of which aim to reduce scar formation. Drawbacks of endoscopic techniques, however, include a steep learning curve as well the need for special technical equipment. A semiopen approach without endoscopic assistance was presented, characterized by a short transverse incision in the groin area without a counterincision distally. This technique was performed in six patients (mean age 48.8 years). Mean incision length was 8.8 cm, and average muscle harvesting time was 49 minutes. The authors suggested the semiopen approach to the gracilis muscle flap because it does not require special instruments and training and is characterized by easy performance and a short incision in the inconspicuous groin area with resultant better cosmesis.


The authors suggested that rather than use the traditional skin island design for the gracilis flap, orienting the skin paddle transversely avoids the large longitudinal incision, placing it inconspicuously in the groin area.


The authors described a technique for using pedicled gracilis muscle flaps to provide groin coverage, reported a summary of their short-term and long-term results, and described why they prefer this reconstructive technique. Twenty pedicled gracilis muscle flaps were placed in 18 patients to treat nonhealing and infected groin wounds. Exposed prosthetic vascular reconstructions were covered with the pedicled gracilis muscle flap in 14 wounds, and in situ autologous vascular reconstructions were covered in four. Seven wound infections were polymicrobial, 10 had a single gram-positive organism, and 1 had a single gram-negative organism. Pseudomonas cultured out in 4 wounds, and Candida in 1 wound. Two patients had a virulent combination of methicillin-resistant Staphylococcus aureus and vancomycin-resistant Enterococcus. Complete healing was initially achieved in all wounds, and no patient died within 30 days of surgery. Two pedicled gracilis muscle flaps failed at 2 weeks and 2 months, respectively, one from tension on the flap pedicle and one from acute inflow occlusion.
Underlying prosthetic reconstruction was salvaged in 12 of 14 wounds; the remaining wounds with autologous reconstructions or exposed femoral vessels all closed successfully. At a mean follow-up of 40 ± 10 months there were no recurrent groin infections. Seven patients died between 2.5 and 28 months postoperatively.


Complex rectovaginal fistulas repair are extremely challenging. Various surgical options have been suggested; nevertheless, none had been universally accepted as the procedure of choice. In this prospective study the author discussed a novel surgical technique using gracilis myocutaneous flap interposition. Eleven patients had fistulas after resection of a pelvic malignancy (10) and rectal endometriosis (1). Primary treatment was pelvic resection; nevertheless, 6 patients had adjuvant chemoirradiation, 2 patients underwent postoperative irradiation, and 2 patients had chemotherapy only. The mean fistula diameter was 2 ± 0.24 cm, and in 8 patients (72.7%) their fistulas were in the middle vaginal third. Repair consisted of wide debridement of fistula margins, followed by gracilis myocutaneous flap interposition with synchronous diverting stomas. Success was defined as healing of fistula after stomal closure. Five patients underwent repair with single gracilis myocutaneous flaps, 2 by simple gracilis muscle, and 4 by double gracilis myocutaneous flaps. Patients had a mean follow-up time of 34.8 ± 5.03 months, and all patients had definitive healing of their fistulas. The median time to stoma closure was 2 months. Four women had at least one early postoperative complications including temporary leak (3), vaginal sepsis (1), partial skin paddle necrosis (1) and donor limb deep venous thrombosis (1). Late morbidities were seen in 3 patients, including vaginal stricture, anorectal anastomotic stricture, and anastomotic tumor recurrence. Rectovaginal septum repair requires adequate debridement of necrotic devascularized tissues, tissue transposition and reconstruction of vaginal wall. Gracilis myocutaneous flaps are ideal for this repair.


The free gracilis perforator flap is a fascio adipocutaneous flap on the medial thigh, based on perforators of the main pedicle of the gracilis myocutaneous flap. An anatomic study was performed using 43 cadaver dissections. The vascular anatomy of the gracilis perforator flap with regard to myocutaneous and septocutaneous perforators was assessed. Clinical application was demonstrated in 14 cases. Myocutaneous perforators of the gracilis muscle pedicle were present in all dissections and were 0.5 mm or more in 93%. Septocutaneous perforators were found in 84% of the dissections, and perforators of 0.5 mm or more were found in 63%. Most myocutaneous perforators were found in the anterior quarter of the muscle where the pedicle enters the gracilis muscle. A constant intramuscular anastomosis between the main and second vascular pedicles of the gracilis was demonstrated that allowed design of an extended gracilis perforator flap.


The authors presented the results of a study conducted to investigate the anatomy of the motor nerve to the gracilis muscle to provide the anatomic basis for harvesting a one-stage gracilis transfer with a long nerve for reanimation of the paralyzed face. An anatomic study was performed on 24 lower limb
specimens (from the pelvis down to the knee) from 12 embalmed cadavers. The motor nerve to the gracilis muscle was dissected from the surface of the muscle to the obturator foramen. Two anatomic regions were defined in the course of the nerve. The first region includes the part of the nerve that can easily be reached through a standard incision in the medial aspect of the thigh; that is, from the surface of the muscle to the posterior border of the adductor brevis muscle and the second region from there to the obturator foramen. Measurements of both anatomic regions and the maximum length of the nerve were taken with a calliper. The anatomic relations of the nerve were also noted and photo-documented. The median maximum length of the motor nerve to the gracilis muscle from the surface of the gracilis to the posterior border of adductor brevis (the first anatomic region) was 7.7 cm (range 6.3 to 10.5 cm); from there to the obturator foramen (second anatomic region), the length was 3.7 cm (range 2 to 6 cm), giving a median length of dissection of the nerve as 11.5 cm (range 9.9 to 13.6 cm). Intraneural dissection of the motor nerve to the gracilis muscle has to be performed proximally in the course of the nerve (the part corresponding to the second anatomic region), just where it runs inside the fascia over the obturator externus muscle.


Fifty thighs from fresh human cadavers were studied to evaluate the feasibility of a double functioning free muscle transfer of the gracilis and adductor longus with single common vascular pedicle anastomosis. Methylene blue intraarterial injection and loupe-magnified dissection were used to demonstrate three groups of vascular patterns in these two muscles. The common vascular pedicles of 88% of their specimen muscles were long enough for possible anastomosis. Ten percent (type B2) were quite short, making microsurgical procedure difficult. Two percent (type A3) of their specimens were not suitable for single anastomosis. Four percent of their gracilis muscles had two major arterial pedicles that branched from the common pedicle in a Y-shaped configuration. If only one pedicle of this type is harvested during a free gracilis muscle transfer, it may cause inadequate flap perfusion. Four specimens were studied using contrast media angiography to confirm that both were Mathes-Nahai type II muscle flaps. This study typed the common vascular pedicle of their sample of gracilis and adductor longus muscles and confirmed the feasibility of double functioning free muscle transfer of the gracilis and adductor longus with single vascular anastomosis.


The authors presented a new combined flap composed of a fasciocutaneous infragluteal flap and a transverse myocutaneous gracilis flap for breast reconstruction. Its main advantage lies in the extensive tissue bulk for transplantation and the option to anastomose the flap to the recipient bed with either of two pedicles, or both.


The transverse myocutaneous gracilis (TMG) flap has received little attention in the literature as a valuable alternative source of donor tissue in the setting of breast reconstruction. The authors presented an in-depth review of their experience with breast reconstruction using the TMG flap. A retrospective review of 111 patients treated with a TMG flap for breast reconstruction in an immediate or a delayed setting was undertaken. Of these, 26 patients underwent bilateral reconstruction, 68 underwent unilateral reconstruction, and 17 underwent reconstruction unilaterally with a double TMG flap. Patients ranged in age from 24 to 65 years (mean 37 years). Twelve patients had to be taken back to the operating room because of flap-related problems, and 9 patients underwent successful revision...
microsurgically, resulting in three complete flap losses in a series of 111 patients with 154 transplanted TMG flaps. Partial flap loss was encountered in 2 patients, whereas fat tissue necrosis was managed conservatively in 6 patients. Low donor site morbidity was an advantage of this flap, with a concealed scar and minimal contour irregularities of the thigh, even in unilateral harvest. Complications included delayed wound healing (10), hematoma (5), and transient sensory deficit over the posterior thigh (49).


The authors presented a case in which the gracilis muscle was transversely split into two free flaps for coverage of two separate defects in a patient with a multisegment fracture of the metatarsal bones and the ankle joint.


After resection of an arteriovenous malformation of the upper and lower lips and commissure the authors performed reconstruction with a forearm flap combined with a free gracilis muscle transfer. First the motor nerve of the gracilis muscle was anastomosed to a buccal nerve branch in the cheek. In a second operation, the vermilion was reconstructed with an oral mucosal graft, and the upper lip skin was reconstructed with a local flap. The patient obtained good oral sphincter function for eating, speaking, and inhalation.


The gracilis myocutaneous free flap provides an alternative for autologous breast reconstruction. It avoids abdominal donor site morbidity, allows quicker recovery, provides an alternative in a thin patient because of its hidden and acceptable donor site, and allows supine positioning for harvest and inset in a timely fashion. The authors conducted a retrospective review of all autologous postmastectomy reconstructions performed between January 2005 and March 2008. All patients receiving gracilis myocutaneous flap reconstruction for postmastectomy defects were included in the study. Office and hospital charts were reviewed. The authors concluded that the gracilis myocutaneous free flap provides an alternative breast reconstruction option for today’s breast cancer patient. It allows a quick harvest in the supine setting, creation of a moderate breast volume, consistent anatomy, and acceptable donor site morbidity with good contour.


The gracilis myocutaneous flap has limited functional donor site morbidity and effectively contours genitoperineal reconstructions. When harvested using a traditional vertical skin paddle, distal-tip necrosis (secondary to inconsistent perforator anatomy) is a well-documented complication. Orienting the skin paddle transversely provides a reliable alternative with a shorter rotational arc but results in a more conspicuous deformity and smaller skin paddle when primary closure is desired. On the basis of recent anatomic studies, the authors designed a pedicled gracilis myocutaneous flap with a bilobed cutaneous paddle to maximally incorporate both the transverse and longitudinal dimensions of the flap’s nearly circular angiosome. The bilobed design allows harvest of a larger transverse skin flap (with a shorter arc of rotation) while a shorter, more dependable vertical skin flap is inset into the transverse flap donor site (rather than inside the critical wound bed).


The transverse myocutaneous gracilis free flap with a transverse orientation of the skin paddle in the proximal third of the medial thigh region allows the surgeon, in selected patients, to take a moderate amount of tissue for autologous breast reconstruction. Donor site morbidity is similar to that of a classic medial thigh lift. The authors discussed indications for this flap in autologous breast reconstruction and the surgical technique. From August 2002 to March 2003, 10 patients underwent autologous breast reconstruction with 12 transverse myocutaneous gracilis free flaps. The patients’ ages ranged from 26 to 48 years (median 40 years). Of these, 2 BRCA-positive women received bilateral breast reconstructions after prophylactic skin-sparing mastectomy, and 8 patients received immediate breast reconstruction after skin-sparing mastectomy in early stage breast cancer. Mean follow-up of the 10 patients was 5 months (range 1 to 9 months). We had no free flap failure. Four patients had small areas of ischemic skin necrosis related to very thin preparation of the skin envelope after skin-sparing mastectomy without altering the final aesthetic results. Cosmetic evaluation of the reconstructed breasts and thigh donor site by two plastic surgeons showed good results in 9 patients and fair results in 1 patient. There was no functional donor site morbidity caused by harvesting the gracilis flap. The transverse myocutaneous gracilis flap is a valuable alternative for immediate autologous breast reconstruction after skin-sparing mastectomy in patients with small and medium-sized breasts and inadequate soft tissue bulk at the lower abdomen and gluteal region.


The transverse myocutaneous gracilis (TMG) flap has been used in autologous breast reconstruction, but disadvantages include a small flap volume; therefore it is only used in small to moderate breast reconstructions. We investigated the vascular territory of this flap and the possibility of extending its dimensions. Ten circumferential thigh adipocutaneous flaps attached to the gracilis muscle were harvested from adult cadavers. Parameters recorded were diameter and length of pedicles, distance of pedicles from pubis, and number and locations of cutaneous perforators. The major pedicles were injected with contrast and subjected to three-dimensional CT scanning. Images were viewed using both General Electric and TeraRecon systems, and the vascular territories were measured. Flaps were then incised to include only tissue that was perfused with contrast, and measured for weight and volume. The major pedicle had a mean length of 6.7 cm, diameter of 2.2 mm, and distance from pubis of 8.6 cm. There was a mean of 4.3 cutaneous perforators associated with this flap. Three-dimensional images from contrast injection of the major pedicle showed a cutaneous vascular territory that extended more posteriorly than anteriorly, and had a vertical component. Tissue perfused with contrast had a mean weight of 573 g and a volume of 617 ml. Two clinical cases were included to show applications of the extended TMG flap.
ANATOMIC LANDMARKS

**Landmarks**  Long, thin, superficial muscle that runs from the anterior superior iliac spine diagonally to the medial tibial condyle.

**Size**  5 × 40 cm.

**Origin**  Anterior superior iliac spine.

**Insertion**  Medial tibial condyle.

**Function**  Lateral rotation and thigh flexion.

**Composition**  Muscle.

**Flap Type**  Type IV.

**Dominant Pedicle**  Segmental branches of the superficial femoral artery.

**Nerve Supply**  *Motor:* Femoral nerve.
Section 12D

THIGH

Sartorius Flap

CLINICAL APPLICATIONS

Regional Use
- Groin
- Knee

Specialized Use
- Femoral vessel and graft coverage
ANATOMY OF THE SARTORIUS FLAP

**Dominant pedicle:** Six or seven segmental branches of superficial femoral artery and vein enter the muscle on its deep or medial surface
ANATOMY

Landmarks  Long, thin muscle that extends from the anterior superior iliac spine diagonally to the medial tibial condyle.
Composition  Muscle.
Size  5 × 40 cm.
Origin  Anterior superior iliac spine.
Insertion  Medial tibial condyle.
Function  Provides lateral rotation and thigh flexion.

Arterial Anatomy (Type IV)

Dominant Pedicle  Segmental branches of superficial femoral artery
Regional Source  Superficial femoral artery.
Length  2 to 3 cm.
Diameter  1 mm.
Location  Six or seven segmental perforators enter the muscle on its deep or medial surface.

Venous Anatomy

Venae comitantes that run with the superficial femoral perforators and drain to the superficial femoral vein.

Nerve Supply

Motor  Femoral nerve.
VASCULAR ANATOMY OF THE SARTORIUS FLAP

Fig. 12D-2

Dominant pedicle: Six or seven segmental branches of superficial femoral artery and vein (arrows)
**FLAP HARVEST**

**Design and Markings**

Any incision overlying the muscle will provide access to it. The incision can be along the line from the anterior superior spine to the medial tibial condyle. However, the muscle may be accessed through the wound it is meant to reconstruct or through longitudinal incisions that allow access to the muscle as well as the reconstructive site.

![Marking for incision for superior muscle elevation](image1)

![Marking for incision for inferior muscle elevation](image2)

*Fig. 12D-3*

**Patient Positioning**

The patient is placed in the supine or frog-leg position.

**GUIDE TO FLAP DISSECTION**

Once the skin is incised, dissection proceeds immediately down to the superficial fascia. The sartorius muscle is defined and the muscle is exposed along its required length. Because the blood supply enters deeply or more medially, the surgeon must exercise care dissecting along the medial border. For use as a standard turnover flap, the muscle is elevated from lateral to medial, with identification of its segmental perforators. The perforators are spared and the muscle is divided superiorly, inferiorly, or both superiorly and inferiorly to allow the muscle to transpose over the defect. At times, with enough longitudinal dissection of the muscle, no division is necessary, so turnover advancement can be performed.
ARC OF ROTATION
For the sartorius muscle to remain viable, its segmental perforators must be kept largely intact. The arc of rotation must therefore be generated by release of the muscle from its origin or insertion, or anywhere along its length, with rotation of the flap toward its vessels. Because of this limitation and the superficial nature of the muscle, advancement superiorly to the groin crease and inferiorly to the medial patella is the limitation of its reach. Carrying a skin paddle with this flap is not recommended because of the limited number of perforators emanating from the muscle and the thinness of the muscle itself.

Fig. 12D-4

A
Medial transposition, no cuts

B
Medial transposition, superior muscle divided

C
Medial transposition, superior and inferior muscle divided
FLAP TRANSFER
The flap may be transferred by simple advancement of the muscle if there is enough laxity and the defect is close. Superior division of the muscle may aid in the arc of rotation and length of the muscle for the reconstruction. Similarly, sometimes inferior division provides a better release of the muscle for the reconstructive need. Both superior and inferior division is routinely performed. The presence of multiple perforators in the segment of muscle that is divided must be confirmed.

FLAP INSET
Absorbable sutures are used to tack the muscle in place for its reconstructive purpose. If the muscle has not been divided either superiorly or inferiorly, there will be tension on the muscle, especially if the patient is ambulatory, and adequate suturing should be performed to maintain the muscle’s position. Not uncommonly, mobilization of the subcutaneous tissue above the muscle rotation allows primary closure over the rotated muscle. Otherwise, the muscle is available for skin grafting for closure.

DONOR SITE CLOSURE
Normally, primary closure of all donor sites is possible.
CLINICAL APPLICATIONS

This 78-year-old woman presented with an exposed saphenous vein patch after an aneurysm repair that resulted in a chronic wound.

Fig. 12D-5  A, A chronic wound with exposed graft under a fibrinous rind. B, The wound is seen after debridement and exposure of the sartorius muscle, which was available for reconstruction. C, The muscle was divided proximally and the muscle transposed medially to cover the exposed repair. All perforators were maintained. The reconstruction was then treated with negative-pressure dressings for 2 months. Ultimately a small skin graft was required. (Case supplied by MRZ.)

This 51-year-old man presented with an exposed Gore-Tex graft in the right groin after bypass surgery for arterial insufficiency.

Fig. 12D-6  A, Right groin wound with an exposed graft (arrow) and some surrounding fibrinous rind. The clamps are grasping the sartorius muscle, which is usually present laterally in such cases. B, The muscle was divided at the top and bottom of the wound and easily transposed to cover the exposed graft. (Case supplied by MRZ.)
This 40-year-old man had condylomata, one of which developed into a squamous cell carcinoma that required radical excision.

**Fig. 12D-7**  
A, Preoperative view of a bilateral groin condyloma and penile condyloma. B, Defects after wide excision of the groin and partial penectomy. The femoral vessels were exposed on the right. It was decided that one of the wounds could be closed primarily, enlarging the contralateral wound, which would require a flap. C, The sartorius was transposed on the right by dividing both above and below the required muscle and easily rotating it over the vessels. D, A primary closure was obtained on the right, and a tensor fascia lata flap was used for closure of the left wound. (Case supplied by MRZ.)
Pearls and Pitfalls

- The sartorius is a first-line flap for coverage of femoral bypass grafts.
- With this flap the blood supply is maintained, even after other vascular procedures or complications.
- The sartorius muscle should always, at a minimum, be dissected through the wound to establish its availability.
- The overlying skin paddle is unreliable.

EXPERT COMMENTARY
Michael R. Zenn

Indications
The sartorius muscle is an expendable muscle that is the primary choice for coverage of exposed femoral prostheses or wounds of the femoral triangle.

Advantages
Despite previous vascular surgery in the area and the commonly associated fibrinous rind one sees with infection and chronic wounds, and likely because of its diagonal course in the thigh, the sartorius muscle is surprisingly available in most cases of exposed groin prostheses. Usually, even when disease is present in the superficial femoral arterial system, the collateral flow through small perforators is often adequate to perfuse the segment of sartorius flap needed for reconstruction.

Recommendations
Technique
After an area is debrided and the vascular surgeons have decided whether to remove the area of graft, the reconstructive surgeon starts dissection in the wound and elevates the subcutaneous plane laterally until the sartorius muscle is encountered. Staying superficial will help avoid injury to the segmental vessels. Sometimes a counterincision or extension of the wound is required for visualization.

Once the lateral border of the muscle is identified, it is elevated. I prefer to keep a minimum of three perforators attached to the sartorius muscle. I divide the muscle just superior to the most proximal perforator and just distal to the most distal perforator. This segment of muscle is then well supplied by its perforators and allows the muscle to simply transpose like an open book over any exposed graft or difficult wound. It is rare to find perforators through the sartorius muscle; therefore it is unwise to attempt to carry a skin island on this muscle, because these attempts will be fraught will failure.
Postoperative Care
All of these patients are given DVT prophylaxis if they are not already on a blood thinner therapeutically. I do try to get them out of bed and even ambulate early, but often comorbidities or the problem necessitating the surgery prevents this. These wounds will drain fluid or lymph for some time, so I place a drain and leave it for 2 to 4 weeks. This is probably a good indication for negative pressure wound therapy over the incision to secure closure and remove weeping from the wound.

Take-Away Messages
Because of the segmental nature of the sartorius muscle, its use outside the area of the thigh is not practical. The sartorius flap’s applicability to cover exposed vessels is often a nice adjunct to larger soft tissue reconstructions in the pubic or groin areas, where the reconstructive flap provides good skin coverage but not specific coverage over the vessels (see Fig. 12H-14, Section 12H).

Bibliography With Key Annotations

The complexity of variables associated with vascular surgical site infections (VSSI) often contribute adversely to reinfection, limb salvage, and mortality rates. This report detailed the authors’ experience with the selective use of a sartorius muscle flaps (SMF) as part of an overall treatment strategy focused on staged surgical debridement (SSD) to control prosthetic graft bed infection before a graft preservation or revision plan. They concluded that selective utilization of SMF as part of SSD treatment plan in an attempt to achieve graft bed sterilization can effectively control the complex infectious process allowing for potentially improved outcomes for in situ or preservation graft salvage techniques. Lifelong graft surveillance is recommended.


The sartorius muscle is a superficial muscle of the thigh that possesses highly suitable qualities for many uses in local transposition and free muscle transfer. However, a paucity of description of the neurovascular anatomy of the sartorius has contributed to its infrequent use in these roles. Both human and canine studies were undertaken to delineate the neurovascular anatomy of the sartorius and to determine the role for surgical delay clinically. Fifty-five human cadaveric sartorius muscles and 30 canine cadaveric sartorius muscles underwent angiographic and dissection studies, and the location and course of the vessels and nerves supplying sartorius are described. A subsequent study was undertaken in two live canines in which the vascular supply to the sartorius was evaluated before and after surgical delay. The sartorius is supplied by an average of six or seven vascular pedicles, the size, location, and course of which are described. The nerve supply to the sartorius enters at its proximal end and uniformly arises from a branch of the femoral nerve. Variations in branching patterns and course of nerves and vessels are described. Living canine studies demonstrated the dilatation of intramuscular vessels following surgical delay, with the contrast injection of a single remaining vascular pedicle shown to vascularize the entire length of the sartorius muscle. The authors concluded that the sartorius is highly suitable for local transposition and free muscle transfer for facial reanimation. The neurovascular anatomy is reliable, and the use of surgical delay can augment its vascular supply and increase the arc of rotation for local transposition.

The authors reported a case of a woman with a long-term nonhealing wound below the tibial tubercle that underwent a successful sartorius muscle flap. They also performed an anatomic study of the vascularization of the sartorius muscle. The vascular supply to the distal part of the sartorius muscle was studied in 15 limbs by dissection and after red ink and latex injections. The artery of the sartorius muscle flap arises most of the time from the saphenous artery or the descending genicular artery and is supplied through anastomoses by branches of the posterior tibial artery and the medial inferior genicular artery. The flap is useful for covering wounds around the knee, as well as the proximal and the middle thirds of the leg. The surgical technique is relatively simple, with low morbidity from muscle harvesting.


Groin infections adjacent to vascular bypass grafts continue to be a source of morbidity. The authors reviewed retrospectively nine consecutive patients with early localized groin infections treated at their institution with sartorius or rectus femoris muscle flaps between 1998 and 2002. All wounds were initially opened and drained. Wounds with necrotic tissue were treated with serial surgical debride-ments, with a VAC device, or with wet-to-dry dressing changes. Two bypass grafts were excised and replaced in the presence of marked exposure or pseudoaneurysm. Small wounds were closed with a turnover sartorius flap and larger wounds were closed with either a muscle or myocutaneous rectus femoris flap. Groin wounds healed in all patients without subsequent graft exposure, rupture, or pseudoaneurysm. Local wound therapy with staged debridement and muscle flaps is effective for most early localized graft infections.


Ilioinguinal dissection is associated with a high rate of lymphatic complications. Prolonged lymph flow causes greatest concern and preventive strategies are needed. The authors reported their retrospective study of 28 consecutive patients who underwent groin dissection for melanoma metastases to evaluate the influence of sartorius muscle transposition on lymph flow. Modification of the surgical technique with transposition of the sartorius muscle was not associated with reduced drainage time. A two-stage approach, with initial sentinel lymph node resection and lymph node dissection in a second operation, led to shortened duration of the lymph flow. Prolonged lymphorrhea was more frequent in older, obese patients affected by diabetes mellitus and hypertension.


Inguinal lymphadenectomy is associated with considerable morbidity, and several attempts have been made to minimize the morbidity by well-vascularized flaps of adequate bulk to obliterate the dead space and promote wound healing. In the case of recurrence, the overlying skin is usually involved and the reconstructive surgeon is confronted with exposed femoral vessels and complex groin defects. The authors reported a series of 40 patients that underwent inguinal lymphadenectomy and immediate sartorius transposition for skin malignancies, and 4 patients with recurrence that was treated with radical surgical excision and pedicled anterolateral thigh flap (ALT). They examined complications such as infection, skin necrosis, lymphorrhoea, lymphoedema, and wound healing time. The immediate sartorius transposition was associated with a 7.5% infection rate, 5% superficial skin edge necrosis, 0% of persistent lymph, and 27.5% of mild lymphoedema. All ALT flaps survived completely
and wounds healed uneventfully within 2 weeks without any signs of infection, seroma, or wound dehiscence. Sartorius and ALT flaps are reliable methods for reconstructing the groin after inguinal lymphadenectomy. They ensure a low complication rate with no donor site morbidity and should be the first-line treatment of immediate and secondary groin reconstruction, respectively.


Complex wounds surrounding the knee and proximal tibia pose a significant challenge for the reconstructive surgeon. Most of these defects can be managed using local or regional flaps alone. However, large defects with a wide zone of injury frequently require microvascular tissue transfers to aid in soft tissue coverage and closure of large cavities. The authors described a unique recipient vessel for microvascular anastomosis for free flap reconstruction involving the knee and proximal tibia through anatomic and clinical studies.


The coverage of soft tissue defects around the knee joint presents a difficult challenge for the reconstructive surgeon. Various reconstructive choices are available, depending on the location, size, and depth of the defect relative to the knee joint. However, the knee joint frequently is involved in injuries to the lower leg, which may limit the use of muscle flaps, especially the gastrocnemius muscle. The use of a free flap is preferred for reconstruction involving obliteration of large-cavity defects, but the isolation of recipient pedicle can be difficult because of the extent of injury zone and in cases of chronic infection around the knee. To provide muscle bulk with a reliable vascular supply, the distally based, prefabricated sartorius muscle flap was used as a last resort to reconstruct difficult wounds with chronic osteomyelitis around the knee joint in six patients from June 1995 to May 2001. This method is a two-stage procedure. First, the sartorius muscle is prefabricated by denervation and vascular delay. Silicone sheets are used to increase the vascularity and dimension of the flap. Second, after 3 weeks, the muscle is transposed based on a distal pedicle to reconstruct the soft tissue defect around the knee. The prefabricated sartorius muscle can provide efficient bulk to obliterate the dead space and to cover moderate-size soft tissue defects around the knee joint. This method can be considered to reconstruct the soft tissue around the knee joint when local muscle flaps and free flaps are not feasible.


The authors presented a technique for soft tissue defect closure of the volar and dorsal aspect of the hand and lower arm, with a maximum defect size of 10 by 25 cm. In a 3-year period, defect closure with a pedicled groin flap was performed in 14 patients. Indications for this procedure included thumb reconstruction for lengthening and defect closure after amputation and burn injury; soft tissue reconstruction of the dorsum of the hand after detachment and infection; soft tissue reconstruction of the distal part of the lower arm, wrist, and palm after complex and combined trauma; and plastic reconstructive preservation of multiple fingers with subsequent phalangealization and syndactyly release, respectively. In all patients, complete soft tissue coverage and flap survival was achieved. The functional and aesthetic result was satisfactory in all cases.


The authors presented the arterial and venous anatomy around the knee and provided a clinical case that demonstrated the distally based greater saphenous venoadipofascial-sartorius muscle combined flap with venous anastomosis so that the reverse venous flow changes to a normal flow along the direction of the venous valves.

**Femoral wound complications can threaten vascular grafts. Muscle flaps can be used to facilitate soft tissue coverage and graft salvage.** The authors reported a series of sartorius flaps performed by vascular surgeons in the treatment of complicated femoral wounds. Rotational sartorius flaps were performed to attempt salvage of underlying vascular grafts. They reviewed a prospective database to determine the outcomes of sartorius flaps on facilitating wound healing and graft salvage and patency. From 2005 to 2008, 21 sartorius flaps were performed in infected or threatened femoral wounds. Original operations included femoral endarterectomy with patch repair in 8 patients, aortofemoral graft in 6, axillofemoral graft in 4, and femoral-distal bypass in 3. Complete wound healing occurred in 18 patients. Primary wound closure was achieved in 7 patients. Secondary wound closure was achieved in 11 patients, with a mean healing time of 2.3 months. All vascular reconstructions remained patent at the 9.5-month follow-up. Sartorius muscle flaps are effective at facilitating complicated femoral wound healing while maintaining graft salvage and patency.


The authors evaluated the effect of muscular pedicle bone grafts with sartorius or tensor fascia latae and sartorius transfer in fresh transcervical or subcapital fractures of the femoral neck. Thirty cases of fresh transcervical and subcapital fractures of the femoral neck were treated by tail breakable screws and sartorius pedicle bone grafts (single muscular pedicle [SMP] group). The other 23 cases were treated by cannulated pressure screws and bone grafts with the muscular pedicles of both sartorius and tensor fascia latae (double muscular pedicles [DMP] group). Fifty-two patients were followed for 3 to 5 years (mean 4 years). In the SMP group, 10 patients showed poor therapeutic results. Excellent therapeutic effects were achieved in all patients in the DMP group. The transcervical or subcapital fractures of the femoral neck can be treated by double muscular pedicles bone graft. The bone graft with double muscular pedicles is more effective than single sartorius muscular pedicles for fresh transcervical and subcapital fractures of the femoral neck.


Few studies have assessed the vascular supply of the sartorius muscle and overlying skin paddle and its potential in reconstructive surgery. In this study the authors used three-dimensional and four-dimensional imaging to analyze the segmental vascularity of the muscle, as well as the overlying skin paddle, to define arcs of rotation based on its major pedicles. Thirty sartorius muscles and the circumferential skin of the thigh were harvested from adult cadavers. Anatomic considerations such as number of pedicles, location, diameter, and length, were recorded. Three-dimensional and four-dimensional CT angiography was used to measure the length of muscle perfused by a single pedicle defined as a major pedicle. Then the area of cutaneous territory supplied by each major pedicle was calculated. The sartorius muscle is supplied by six to eight vascular pedicles. Two clusters of major pedicles (diameter greater than 1.8 mm) were described (proximal and distal), which are located 18 to 25 cm and 35 to 44 cm from the anterior superior iliac spine, respectively. The proximal major pedicle perfuses almost 80% of the muscle, and the distal major pedicle perfuses almost 90%. The average area of skin perfused was 330 cm. This study indicated a greater anatomic assurance of the potential use of the sartorius muscle and its overlying skin as a local transposition and free flap. The vascular supply of the muscle and skin by two major pedicles allows two pivot points for muscular or myocutaneous flaps.


The sartorius muscle is frequently used as a surgical flap. This study described sartorius nerve and artery distribution in adult men. Fifty-three specimens obtained from fresh cadavers were prepared:
32 specimens were injected with a red-colored gelatin solution through the femoral artery so that intramuscular arteries and nerves were dissected; 6 specimens were injected with barium sulfate solution through the femoral artery for radiography; 7 specimens were injected with a Chinese ink solution, also through the femoral artery, for diaphanization; 7 specimens were injected with a solution of vinyl acetate, through the femoral artery, to obtain an arterial cast; and 1 specimen was cut and colored by Masson's trichrome. Sartorius branching patterns of the nerve and artery were schematized. The authors detailed their findings. The nerve branches were divided into two or three territorial branches, and then into four or five segmental branches, running longitudinally inside the muscle. The muscles showed an average length of 44.81 cm. The sartorius muscle is a segmented structure that can be divided into as many as five arterial and nervous segments. In the proximal and middle parts, the muscle has better arterial supply. The segments can be filled by adjacent pedicles because of an elongated net of anastomoses, which allows a longer arc of rotation in the construction of pedicled flaps.


The authors reported a retrospective analysis of 53 patients with 56 proximal sartorius muscle flaps. The indication for a flap procedure was postoperative recalcitrant lymphorrhea in 9 patients, graft at risk in 13, and graft infection in 34. Preoperative and postoperative patencies of the superficial femoral artery (SFA) and profundal femoral artery (PFA) were documented. Flap viability, wound healing, and limb salvage were examined at follow-up. The authors concluded that biologic protection procedures as local muscle flaps are vital adjuncts to vascular surgery techniques in the treatment of complicated wounds in the groin. Occlusion of the SFA in the presence of a patent PFA is not associated with an increased risk of flap loss in proximal sartorius muscle rotational flaps.


A variety of muscle flaps have been described to treat complex groin wounds associated with infected and/or exposed femoral vessels or vascular grafts and persistent lymphatic leaks, and for prophylaxis against wound breakdown following inguinal lymphadenectomy. The sartorius muscle flap has several advantages over other muscle flaps: it is immediately adjacent to the groin, it is easy to prepare, and the harvest causes no functional morbidity. Despite these advantages, the flap's reliability has been questioned because of the segmental blood supply to the muscle and the flap's limited arc of rotation. To improve the reliability of the flap, the authors defined the proximal vascular anatomy of the sartorius muscle in 20 human cadavers and assessed the correlation with 20 clinical cases. They described a technique for the harvest of the sartorius muscle transposition flap that preserves the proximalmost pedicle. They dissected 40 sartorius muscles in 20 human preserved cadavers. They also performed 21 sartorius muscle transposition flap procedures in 19 patients for a variety of complex groin wound complications, including infection (10), lymphadenectomy (4), lymphatic leak (3), exposed femoral vessels (3), and a high-risk wound (1). The location of the proximalmost vascular pedicle with respect to the anterior superior iliac spine was measured in each cadaveric dissection as well as in each clinical case. Outcomes were assessed in the clinical cases with respect to wound healing. The proximal pedicle of the sartorius muscle was consistently located 6.5 cm from the anterior superior iliac spine. Preservation of the proximal pedicle during dissection ensures the viability of the sartorius muscle transposition flap for the treatment of complex groin wounds.
ANATOMIC LANDMARKS

Landmarks  Posterior thigh musculature is composed of the biceps femoris, semimembranosus, and semitendinosus muscles, which run from the ischial tuberosity to the tibia, occupying the posterior compartment of the thigh. The biceps femoris is the most lateral of these “hamstring” muscles.

Size  15 × 45 cm when including all muscles; skin involves the posterior surface of the thigh advanced only as transposition.

Origins  
- **Biceps femoris**: Long head: Ischial tuberosity; short head: linea aspera of femur.  
- **Semimembranosus**: Ischial tuberosity.  
- **Semitendinosus**: Ischial tuberosity.

Insertions  
- **Biceps femoris**: Head of fibula.  
- **Semimembranosus**: Medial condyle of tibia.  
- **Semitendinosus**: Medial condyle of tibia.

Function  Three powerful flexors of the knee. The biceps femoris tightens the iliotibial tract, important for lateral knee stabilization, and is a major external rotator of the knee.

Composition  Muscle, myocutaneous.

Flap Type  Type II.

Dominant Pedicles  
- **Biceps femoris**: Long head: First perforating branch of profunda femoris artery and venae comitantes; short head: second or third perforating branch of profunda femoris artery and venae comitantes.  
- **Semimembranosus**: First perforating branch of profunda femoris artery and venae comitantes.  
- **Semitendinosus**: First perforating branch of profunda femoris artery and venae comitantes.

Minor Pedicles  
- **Biceps femoris**: Long head: Second perforating branch of profunda femoris artery and venae comitantes; short head: superior lateral genicular artery and venae comitantes.  
- **Semimembranosus**: (1) Second or third perforating branch of profunda femoris artery and venae comitantes; (2) branch of inferior gluteal artery; (3) branch of superficial femoral artery.  
- **Semitendinosus**: (1) Muscular branch of inferior gluteal artery; (2) descending branch of medial femoral circumflex femoral artery; (3) inferior medial genicular artery and venae comitantes.

Nerve Supply  
- **Motor**: Sciatic nerve branches.  
- **Sensory**: Posterior cutaneous nerve of thigh (S1 to S3).
Section 12E

THIGH

Biceps Femoris (Hamstring) Flap

CLINICAL APPLICATIONS

Regional Use
  Ischium
  Thigh

Specialized Use
  Pressure sores
ANATOMY OF THE BICEPS FEMORIS (HAMSTRING) FLAP

Composite biceps femoris, semimembranosus, semitendinosus muscles

Biceps femoris muscle

Semimembranosus muscle

Semitendinosus muscle

Fig. 12E-1
ANATOMY

Landmarks  The biceps femoris is one of three posterior thigh “hamstring” muscles that make up the posterior thigh compartment. These muscles all originate from the ischium. The biceps femoris is the lateralmost muscle, inserting distally into the fibula. The semimembranosus and semitendinosus muscles insert on the medial condyle of the tibia; the semimembranosus is medialmost.

Composition  Muscle, myocutaneous.

Size  Muscle: 15 × 45 cm when using all muscles. Skin: Uses the posterior thigh as a V-Y or large transposition flap with primary closure of the donor site.

Origins  **Biceps femoris:** Long head: the ischial tuberosity; short head: the linea aspera of the femur. **Semimembranosus:** Ischial tuberosity. **Semitendinosus:** Ischial tuberosity.

Insertions  **Biceps femoris:** Head of the fibula. **Semimembranosus:** Medial condyle of the tibia. **Semitendinosus:** Medial condyle of the tibia.

Function  These three muscles are powerful knee flexors. The biceps femoris tendon tightens the iliotibial tract, which is important in stabilization of the lateral knee. The biceps femoris is also a major external rotator of the knee, while the semimembranosus and semitendinosus contribute to internal rotation of the knee.
ANATOMY OF THE BICEPS FEMORIS MUSCLE

Fig. 12E-1

Dominant pedicle of long head: First perforating branch of profunda femoris artery
Minor pedicles of long head: Second perforating branch of profunda femoris artery; branch of inferior gluteal artery
Dominant pedicle of short head: Second or third perforating branch of profunda femoris artery
Minor pedicle of short head: Superior lateral genicular artery
Arterial Anatomy (Type II)

BICEPS FEMORIS MUSCLE

Dominant Pedicle (long head)  
*First perforating branch of profunda femoris artery*

**Regional Source**  Profunda femoris artery.

**Length**  2 to 3 cm.

**Diameter**  1 to 2 mm.

**Location**  Medial aspect of the muscle.

Minor Pedicle (long head)  
*Second perforating branch of profunda femoris artery*

**Regional Source**  Profunda femoris artery and vein.

**Length**  2 to 3 cm.

**Diameter**  0.5 to 1.5 mm.

**Location**  Lower part of the muscle medially.

Minor Pedicle (long head)  
*Branch of inferior gluteal artery*

**Regional Source**  Inferior gluteal artery.

**Length**  1 to 2 cm.

**Diameter**  0.5 to 1 mm.

**Location**  At the origin of the muscle.

Dominant Pedicle (short head)  
*Second or third perforating branch of profunda femoris artery*

**Regional Source**  Profunda femoris artery.

**Length**  2 to 3 cm.

**Diameter**  0.5 to 1 mm.

**Location**  Enters the muscle close to its origin from the femur.

Minor Pedicle (short head)  
*Superior lateral genicular artery*

**Regional Source**  Popliteal artery.

**Length**  3 to 4 cm.

**Diameter**  0.5 mm.

**Location**  Distal into the muscle belly.
ANATOMY OF THE SEMIMEMBRANOSUS MUSCLE

Fig. 12E-1

Dominant pedicle: First perforating branch of profunda femoris artery
Minor pedicles: Second or third perforating branch of profunda femoris artery; branch of inferior gluteal artery; branch of superficial femoral artery
SEMIMEMBRANOSUS MUSCLE

Dominant Pedicle  *First perforating branch of profunda femoris artery and venae comitantes*

**REGIONAL SOURCE**  The profunda femoris artery and vein.

**LENGTH**  2 to 3 cm.

**DIAMETER**  1 to 2 mm.

**LOCATION**  Enters on the deep lateral surface of the muscle.

Minor Pedicle  *Second or third perforating branch of profunda femoris artery and venae comitantes*

**REGIONAL SOURCE**  Profunda femoris artery and vein.

**LENGTH**  1 to 2 cm.

**DIAMETER**  1 to 2 mm.

**LOCATION**  Enters on the deep lateral surface of the muscle.

Minor Pedicle  *Branch of inferior gluteal artery and venae comitantes*

**REGIONAL SOURCE**  Inferior gluteal artery and vein.

**LENGTH**  1 to 2 cm.

**DIAMETER**  0.5 to 1 mm.

**LOCATION**  At the origin of the muscle.

Minor Pedicle  *Branch of superficial femoral artery and venae comitantes*

**REGIONAL SOURCE**  Superficial femoral artery.

**LENGTH**  2 cm.

**DIAMETER**  0.5 to 1 mm.

**LOCATION**  At the insertion of the muscle. *Note:* This muscle may be considered to have a type III blood supply when its vascular pedicles from each of the perforating branches are of equal size.
ANATOMY OF THE SEMITENDINOSUS MUSCLE

Semitendinosus muscle

**Fig. 12E-1**

**Dominant pedicle:** First perforating branch of profunda femoris artery

**Minor pedicles:** Muscular branch of inferior gluteal artery; descending branch of medial circumflex femoral artery; superior medial genicular artery
SEMITENDINOSUS MUSCLE

Dominant Pedicle  
**First perforating branch of profunda femoris artery**

**REGIONAL SOURCE**  
Profunda femoris artery.

**LENGTH**  
2 to 3 cm.

**DIAMETER**  
1 to 2 mm.

**LOCATION**  
Enters on the deep lateral surface of the muscle.

Minor Pedicle  
**Muscular branch of inferior gluteal artery**

**REGIONAL SOURCE**  
Inferior gluteal artery.

**LENGTH**  
1 to 2 cm.

**DIAMETER**  
0.5 to 1 mm.

**LOCATION**  
Enters the muscle at the origin.

Minor Pedicle  
**Descending branch of medial femoral circumflex artery**

**REGIONAL SOURCE**  
Profunda femoris artery.

**LENGTH**  
1 to 2 cm.

**DIAMETER**  
0.5 mm.

**LOCATION**  
Upper portion of the muscle.

Minor Pedicle  
**Inferior medial genicular artery**

**REGIONAL SOURCE**  
Popliteal artery.

**LENGTH**  
1 to 2 cm.

**DIAMETER**  
0.5 mm.

**LOCATION**  
Enters the muscle near its tendon.

Venous Anatomy

Accompanying paired venae comitantes that mirror the arterial anatomy.

Nerve Supply

**Motor**  
Branches of the sciatic nerve.

**Sensory**  
Posterior cutaneous nerve of the thigh (S1 to S3).
Vascular Anatomy of the Biceps Femoris (Hamstring) Flap

Dominant pedicle of long head: First perforating branch of profunda femoris artery ($D_1$)
Minor pedicles of long head: Second perforating branch of profunda femoris artery ($D_2$); branch of inferior gluteal artery ($m_1$)
Dominant pedicle of short head: Second ($D_2$) or third ($D_3$) perforating branch of profunda femoris artery
Minor pedicle of short head: Superior lateral genicular artery ($m_2$)
Vascular Anatomy of the Semimembranosus Flap

Fig. 12E-3

Dominant pedicle: First perforating branch of the profunda femoris artery (D)
Minor pedicles: Second or third perforating branch of profunda femoris artery (m₁); branch of inferior gluteal artery (m₂); branch of superficial femoral artery (m₃)
Vascular Anatomy of the Semitendinosus Flap

Fig. 12E-4

**Dominant pedicle:** First perforating branch of profunda femoris artery (D)

**Minor pedicles:** Muscular branch of inferior gluteal artery (m₁); descending branch of medial circumflex femoral artery (m₂); superior medial genicular artery (m₃)
FLAP HARVEST

Design and Markings
The skin paddle should overlie the muscles of the posterior thigh for an advancement flap, as a V-Y or as a semicircular advancement flap. Either the biceps femoris alone or all of the posterior thigh muscles can be included in the flap, increasing its blood supply. Incorporating the entire posterior thigh skin in the design is recommended for advancement and best perfusion. A V-Y design allows the greatest advancement of the flap toward the ischium.

These flaps are commonly used in patients who are paralyzed and nonambulatory to reconstruct decubitus defects. The muscles may be hard to identify because of atrophy and may have limited bulk; therefore a wide design is helpful in capturing the blood supply.

Patient Positioning
Placing the patient in the prone position is most useful for treatment of the ischial or thigh area and for harvesting this flap. The amount of flexion at the hip should be limited to allow maximal advancement of this flap.
GUIDE TO FLAP DISSECTION

Once the flap is incised and deepened down to the fascia, identification of the hamstring muscles is important. Superiorly, the bulk of the musculature originating from the ischium is divided; this division should be kept at the bony interface to minimize injury to the blood supply. Distally, the muscle bellies can be individually isolated as they insert into the medial tibia and laterally into the fibular head and divided. Because the blood supply is largely segmental, the surgeon should attempt to mobilize the flap and advance this with minimal division of the underlying attachments and therefore the blood supply. By releasing the origin and insertion and medial and lateral attachments of these muscles, one will generate mobility of the flap so it can be advanced upward for use with ischial defects. Because of the segmental nature of the blood supply, one should avoid isolating muscles and dividing distal blood supply for a proximal rotation or proximal blood supply for a distal rotation. Although either flap rotation is possible, depending on the particular anatomy of the patient, both are thought to be unreliable in general as isolated muscle transpositions. For advancement and fill of an ischial defect, both muscle and deepithelialized skin paddle should be used. By advancing the flap with the release of the muscular origin, insertions, and lateral attachments, one can obtain up to 10 cm of advancement.

Fig. 12E-6  A, Skin design with the flap width equal to the length of the bursa, not the smaller skin defect. B, The V-Y flap is incised and advanced after muscle release superiorly, inferiorly, medially, and laterally. C, The V-Y closure supports the advanced flap and allows tension-free closure. Note that some of the skin paddle has been deepithelialized and buried to add bulk to obliterate the bursa.
**FLAP VARIANTS**

- Muscle-only superiorly based flap
- Inferiorly based (reverse) flap

**Reverse Flap**

The use of the biceps femoris as a distally based flap for lower thigh and superior knee reconstruction has been described; one must have an adequate distal minor pedicle to do so. The biceps femoris can be the sole basis of a muscular flap; however, in most patients this is not a reliable flap and is not recommended for an ambulatory patient, because it sacrifices an essential muscle of the leg.
ARC OF ROTATION

**V-Y Flap**

The V-Y flap is the most useful of the posterior thigh myocutaneous flap designs. First, it allows advancement of the skin muscle unit superiorly without the need for a backcut. It also allows readvancement of the flap if pressure sores recur in the ischial area. With full release of the origin and insertion and lateral attachments of the muscle, up to 10 cm of advancement can be obtained. In large wounds or the need for readvancement in a paralyzed patient, division of the sciatic nerve can offer an additional 2 cm of advancement and has no functional significance.

**Semicircular Flap**

An advantage of the semicircular advancement design is that it encompasses the entire posterior thigh and therefore has an excellent blood supply; it is also easier to dissect this flap. Although inferiorly and posteriorly muscular release is required, similar to the V-Y variant, with the semicircular flap design, the base of the flap is not disconnected, which ensures better venous drainage of the skin and a more secure blood supply. Advancement with this flap might be limited, depending on the backcut of the flap for advancement. With full release of the origin and insertion of the muscles and a healthy backcut, advancement of 8 to 10 cm is possible.
FLAP TRANSFER

V-Y and Semicircular Flap
When these flaps are used for an ischial reconstruction, the defect marks the superior portion of the flap. The flap transfers through a direct transposition from the donor site into the recipient site. Both the V-Y and semicircular designs allow advancement of the muscle and skin for bulk for reconstruction.

FLAP INSET

V-Y Flap and Semicircular Flap
With both flaps one should use the advanced muscle to secure the flap superiorly and take tension off the skin closure. These ischial defects often have an associated bursa, and advancing the flap an additional few centimeters and deepithelializing the skin paddle will afford even more bulk for the reconstruction. Because these flaps are inset directly, there is little concern about compression of the pedicle.

DONOR SITE CLOSURE

V-Y Flap
In typical V-Y fashion, closure distally will support advancement of the flap and bear tension on the closure. Again, it is recommended that the design of the flap extend to the popliteal area so that secondary readvancement of the flap can be done with further V-Y advancements.

Semicircular Flap
Once the flap has been advanced with a backcut, there should be enough mobility in the thigh for primary closure. In rare instances, especially in reoperative cases, a skin graft may be required to back-graft the donor site.
CLINICAL APPLICATIONS
This 23-year-old paraplegic man had bilateral ischial pressure sores. Preoperative care in such patients and preparation for surgery is just as important to success as the surgical procedure. Wounds should be clean and show evidence of granulation. This may mean a preliminary surgery for debridement and a period of dressing changes or negative-pressure dressings. Patients should stop smoking and a nutritional evaluation should be performed. Atrophy of surrounding tissues is typical with paraplegia. As is also typical, the skin defect is smaller than the underlying bursa, and flaps should be planned to reconstruct the deep defect, removing the thin overlying skin.

Fig. 12E-9  A, Preoperative view: the wounds are granulating, a sign of adequate nutrition. Flaps were designed to reconstruct the deeper bursa cavity and replace the atrophic skin. B, After flap advancement as V-Y flaps. Note the large size of the flaps, extending distally in the thigh. Also note how much of the atrophic skin could be replaced, because part of the proximal flap was deepithelialized and used to fill the bursal cavity. (Case supplied by MRZ.)
This 58-year-old woman had diabetes, renal failure, peripheral vascular disease, and an infected and necrotic ischial decubitus.

**Fig. 12E-10**  
A, The wound had necrosis without granulation, and there was surrounding cellulitis. The first step was aggressive debridement and treatment of the cellulitis. B, After 2 weeks of dressing changes and preoperative optimization, a healthy, granulating wound could be seen without cellulitis. Note the true size of the defect as the thin overlying skin was resected and the bursa exposed. C, Reconstruction of the defect with a V-Y advancement. The flap is being advanced beyond the visible defect so some proximal deepithelialization can be performed and the cavity filled with viable tissue, obliterating dead space. D, Flap inset. The V-Y closure has the advantage of supporting the flap in its new position, taking tension off the inset. (Case supplied by MRZ.)
This 46-year-old paralyzed man had a clean ischial decubitus.

![Image](image1.png)

**Fig. 12E-11**  
**A**, A semicircular flap was planned, with the design encompassing the entire posterior thigh. The flap could have been based medially or laterally; a medially based flap was chosen in this case, since the defect was more medial, favoring medial rotation.  
**B**, Flap inset. Again, some of the proximal flap was deepithelialized and used to obliterate dead space. (Case supplied by MRZ.)

This 64-year-old paraplegic man had a large ischial decubitus. The bursa in this case was extensive, and the size of the skin opening was misleading.

![Image](image2.png)

**Fig. 12E-12**  
**A**, A V-Y flap was planned. Note that the proximal width of the flap reflects the extent of the bursa, not the skin opening. Thin overlying skin was removed to allow adequate obliteration of the cavity and resurfacing. The larger design was used to allow for possible readvancement in case a pressure sore recurs.  
**B**, Flap inset. Some of the proximal flap was used to obliterate space. The amount of advancement is reflected by the length of the distal donor closure. (Case supplied by MRZ.)
Pearls and Pitfalls

- The biceps femoris flap (posterior thigh flap) is the flap of choice for ischial decubiti, because it leaves other valuable donor sites such as the gluteal and inner and outer thigh areas available for decubiti in these areas.
- The flap is relatively straightforward and easy to dissect, and one would be best served by not skeletonizing or attempting to isolate the underlying blood supply.
- The surgeon must beware of excessive tension on the advancement flap and the shearing of the skin paddle from the underlying musculature.
- Direct pressure must be avoided postoperatively on these advancements with the use of a low-pressure bed or alternative positioning in the prone or lateral positions.
- Although reverse flaps have been described, they are unreliable as the distal minor pedicles are variable.
- The hamstring muscles are critical in ambulatory patients and should not be used as muscle or myocutaneous flaps.
- In a paralyzed patient, division of the sciatic nerve, when needed, will allow an additional 2 cm of advancement and has no functional significance to the patient.

EXPERT COMMENTARY
Michael R. Zenn

Indications
The biceps femoris (posterior thigh flap) is an incredibly useful flap for wounds around the ischial tuberosity and for soft tissue defects of the perineum.

Advantages and Limitations
Because of the functional importance of the muscles, these flaps should only be used in non-ambulatory patients. Because these muscles are essentially supplied by segmental vessels (some major, some minor) the most successful flap designs maintain these segmental blood supplies. Depending on the dominance of the vessels found in a particular patient, certainly isolated muscle advancements or rotations would be reasonable. Keep in mind that the bulk of these muscles in the paralyzed patient is often less than desired and these flaps are most useful as myocutaneous advancements.

Personal Experience and Insights
My personal preference is to use the biceps femoris V-Y myocutaneous flap as the primary flap for ischial pressure sores. Its arc of rotation lends itself to this defect, as the flap is being advanced toward its blood supply. It has a generous amount of skin, fat and muscle which help obliterate the bursa which is often associated with these flaps, and most importantly it spares other donor sites such as the medial thigh, lateral thigh and buttock for secondary problems or the inevitable decubiti in other locations.

Continued
Recommendations

Planning

Use of the flap as a bilateral flap advanced centrally can reconstruct remarkably large central perineal defects as well. Although some have described the turndown of the biceps femoris as a useful flap for supra patellar and popliteal defects, I feel that this is an unreliable flap historically, and depending on the patient, there may be an incredibly small minor pedicle nurturing this flap making its reliability uncertain. There are much better choices such as the gastrocnemius flap or reverse ALT flap. This variant of the flap has not been used in my practice. In an ambulatory patient, I also would favor a free tissue transfer for the lowest morbidity. For extensive defects of the ischium, this flap may require a second flap to help obliterate and close the defects. The key to success in these patients is not only in execution of the flap, but in postoperative management. I recommend a 2-month period of no pressure on the area of reconstruction, either by low-pressure bed or by patient positioning. I also like the fact that the advancement flap can be performed without the need for skin grafting of the donor site, which I have never had to do in my practice.

Bibliography With Key Annotations


Perforator flaps are an important development in reconstructive surgery. The description of new perforator flaps is an open field in anatomical and surgical research. The anatomy of the musculocutaneous perforating vessels of the short head of the biceps femoris muscle was investigated as a possible source for free tissue transfer in 10 fresh cadaver specimens. A series of 10 free biceps femoris perforator flaps for upper extremity reconstruction is described. There were three constant sizable perforators, located at 6 cm (range 5 to 6.5 cm), 11.6 cm (range 10 to 14 cm), and 15.3 cm (range 14 to 17 cm), respectively, from the knee joint line. The distalmost perforator was a branch off the superior lateral genicular artery in all anatomic specimens. The middle perforator was a direct branch off the popliteal artery in 60% of the cases and off the profunda femoris in the remaining 40%. The uppermost perforator was usually a branch off the middle perforator. The flaps of the clinical series were based on the middle perforator (11.6 cm). All 10 free flaps were used for upper extremity trauma coverage, with a 100% success rate, although one flap required pedicle revision because of arterial thrombosis and developed partial necrosis. Donor-site delayed wound healing occurred in two patients. The vascular anatomy is relatively constant. Flap dissection is straightforward under tourniquet control, donor morbidity is low provided a primary closure is possible, and pedicle size is appropriate for repair. When a moderate-size free flap with moderate thickness and a medium-sized pedicle is needed, the biceps femoris perforator flap should be considered in the first-choice group of donor areas.


The authors performed an anatomic study to reappraise the vasculature of the lateral intermuscular septum of the thigh and the muscles associated with it; 12 preserved cadaver legs were used. Several possible new clinical applications of the lateral intermuscular septum and the short head of the biceps femoris were identified as follows: (1) short head of biceps femoris muscle or musculocutal flap based on the second and/or third profunda perforating vessels, or based on the superior lateral genicular vessels,
with or without the iliotibial tract and the deep fascia, and with or without the motor nerve of the short head; (2) transverse extension of the fascial portion of the tensor fascia lata muscle or myocutaneous flap to include the lateral intermuscular septum; (3) the combined use of items 1 and 2; and (4) free septofascial graft using the lateral intermuscular septum and iliotibial tract. It is anticipated that the distally based short head of the biceps femoris muscle flap will be an additional option for repairing defects around the knee, and that a free short head of the biceps femoris muscle flap based on the profunda femoris perforating vessels will be useful in functional reconstruction such as reanimation of the paralyzed face. The lateral intermuscular septum can be incorporated into the short head of biceps femoris muscle flap or into the tensor fascia latae flap, and it also can be used as a free fascial graft. The functional deficit resulting from harvesting the short head of the biceps femoris and the lateral intermuscular septum is minimal, and donor wound at the lateral lower thigh seems to be acceptable.


The authors presented an anatomic study describing the distribution of the cutaneous perforators of both heads of the biceps femoris muscle. They dissected 18 legs from 9 cadavers. The study was centered on the biceps femoris muscle and myocutaneous perforator arteries from both muscular heads. Only perforator arteries with concomitant vein diameters greater than 0.5 mm were selected. The vascular origin and length were also studied. In all cases, measurements were taken from the bicondylar line. The principal vascular origin of the perforator arteries was the popliteal artery in both muscle bellies, while the second arterial vessel in importance was the first and second profunda perforator artery. From these results, the authors deduced that it is always possible to locate perforator arteries in both muscle bellies; most frequently they have intramuscular distribution and are located in the proximity of the vascular septum. Their most common origins are the popliteal artery and first and second profunda perforator artery. Finally, it is possible to design pedicle and free flaps with less morbidity and more versatility than with myocutaneous flaps.


The vascular communication between the heads of the biceps femoris muscle has been established after 25 cadaveric dissections. Perfusion of dye through the long or the short head consistently showed one or two anastomotic bundles. Outflow of dye opposite the site of the perfused head was remarkable in most cases. Intramuscular dissections disclosed broad well-structured vascular networks in all short heads, but this was not true for all long heads. Their observations suggest that the anastomotic vessels alone might support the short head which, when released from its profunda femoris vessels, is adequate to cover lateral knee defects. Depending on the level of the anastomotic vessels, the proximal or the distal part of the short head should be used. A pedicled flap may be used as well, whereas transection of the biceps tendon offers additional mobility.
### ANATOMIC LANDMARKS

**Landmarks**
This thin, bandlike muscle occupies a space laterally in the thigh bordering the rectus femoris muscle anteriorly and the biceps femoris muscle posteriorly. The muscle is usually palpable just distal to the greater trochanter.

**Size**
The muscle is 5 cm wide, 12 cm long, and 2 cm thick at its origin. Skin $15 \times 40$ cm can be transferred but requires skin graft closure of the donor site.

**Origin**
The anterior 5 cm of the outer lip of the iliac crest, extending to the lateral surface of the anterior superior iliac spine. The muscle also originates from the greater trochanter of the femur.

**Insertion**
The fascia lata extension of the TFL inserts into the lateral condyle of the tibia.

**Function**
Knee stabilization.

**Composition**
Muscle, myocutaneous, osteomyocutaneous, perforator fasciocutaneous.

**Flap Type**
Type I.

**Dominant Pedicle**
Lateral femoral circumflex artery.

**Nerve Supply**
*Motor:* Superior gluteal nerve (L4, L5, S1). *Sensory:* Lateral cutaneous branch of T12; lateral femoral cutaneous nerve of the thigh (L2, L3).
Section 12F

THIGH

Tensor Fascia Lata (TFL) Flap

CLINICAL APPLICATIONS

Regional Use
- Groin
- Abdomen
- Trochanter
- Ischium
- Perineum

Distant Use
- Head and neck
- Upper extremity
- Lower extremity
- Abdomen

Specialized Use
- Abdominal wall reconstruction
- Breast reconstruction
- Vaginal reconstruction
Vascular and nerve supply

**Fig. 12F-1**

**Dominant pedicle:** Lateral circumflex femoral artery
ANATOMY

Landmarks
This thin, bandlike muscle occupies a space laterally in the thigh, bordering the rectus femoris muscle anteriorly and the biceps femoris muscle posteriorly. The muscle is usually palpable just distal to the greater trochanter. A line extending from the greater trochanter to the midlateral aspect of the knee bisects the tensor fascia lata (TFL) muscle.

Composition
Muscle, myocutaneous, osteomyocutaneous, perforator fasciocutaneous.

Size
The muscle is 5 cm wide, 12 cm long, and 2 cm thick at its origin. Skin $15 \times 40$ cm can be transferred but requires skin graft closure of the donor site. The osseous segment is $6 \times 4$ cm.

Origin
The anterior 5 cm of the outer lip of the iliac crest, extending to the lateral surface of the anterior superior iliac spine. The muscle also originates from the greater trochanter of the femur.

Insertion
The fascia lata extension of the TFL inserts into the lateral aspect of the knee. The iliotibial tract is formed by a combination of aponeurosis of the superficial portion of the gluteus maximus muscle and a similar aponeurosis of the TFL muscle. The tract descends between the circular fibers of the fascia lata to insert on the lateral condyle of the tibia.

Function
The TFL acts as a knee stabilizer. When the iliotibial tract is taut, the knee is held in extension. This tightening of the tract also stabilizes the hip and the leg in a standing position. However, in all but the most athletic individuals, harvest of the flap is associated with minimal functional morbidity.

Arterial Anatomy (Type I)

Dominant Pedicle

Lateral circumflex femoral artery

Regional Source
Profunda femoris artery.

Length
6 cm.

Diameter
2 to 3 mm.

Location
Leaves the lateral side of the profunda femoris artery and passes deep to sartorius and rectus femoris muscles. Behind the rectus femoris muscle, it gives rise to three branches:

1. Ascending branch to the superior portion of the muscle.
2. A transverse branch supplying the mid and superior portions of the muscle.
3. A descending branch running inferiorly along the muscle, supplying its lower third.

The ascending branch supplies branches to the iliac crest along its origin and is the basis for the osseous combined flap. Multiple myocutaneous perforators measuring 1 mm or less supply the overlying skin and are the basis for the perforator flap.

Venous Anatomy

Two venae comitantes travel with the lateral circumflex femoral artery (LCFA). These venae comitantes are 2 to 4 mm in diameter and join the lateral side of the femoral vein.
Nerve Supply

Motor
The superior gluteal nerve. This nerve has contributions from L4, L5, and S1 and supplies all three abductors of the hip. After exiting above the piriformis muscle, the nerve courses laterally between the gluteus medius and gluteus minimus muscles, entering the TFL on its deep and posterior aspect in the middle third of the muscle.

Sensory
Skin territory is innervated by two distinct sensory nerves: (1) the lateral cutaneous branch of T12, which supplies the upper skin territory over the muscle and origin of the muscle, and (2) the lateral femoral cutaneous nerve of the thigh, with contributions from L2 and L3, which innervate the remaining inferior skin territory. The lateral cutaneous branch of T12 courses anteriorly on the external oblique muscle in the midaxillary line, heading inferiorly and anteriorly. It crosses the iliac crest approximately 6 cm posterior to the anterior superior iliac spine (ASIS). The lateral cutaneous nerve of the thigh enters the thigh 2 cm medial to the ASIS below the inguinal ligament. It remains deep to the TFL, eventually penetrating the muscle and entering the skin 10 cm inferior to the ASIS near the anterior border of the flap.

Vascular Anatomy of the Tensor Fascia Lata (TFL) Flap

Fig. 12F-2

Dominant pedicle: Lateral circumflex femoral artery (D)
FLAP HARVEST

Design and Markings

The skin paddle should overly the muscle in its proximal design. This is best delineated by a line drawn from the ASIS to the lateral condyle of the tibia. This line demarcates the anterior border of the muscle. A line drawn 3 cm posterior to this and parallel represents the tensor muscle; this originates in part from the trochanter, which is palpable. The vascular pedicle should be anticipated 7 to 12 cm distal to the ASIS and can be confirmed with Doppler ultrasound. A flap greater than 9 cm in width will require skin grafting for donor site closure, although this is variable. The distal third of the skin territory is unreliable and requires a delay procedure to ensure its vascularity. The flap design will depend on its use and is most commonly a simple rotation flap, which can be completely incised as an island flap or designed as a V-Y advancement flap.

Fig. 12F-3  A, Flap design. B, The initial incision for elevating the lateral circumflex femoral artery perforator flap follows the upper portion of the vertical line drawn between the anterior superior iliac spine and the lateral border of the patella. The intermuscular relationship of the source vessel to the tensor fascia lata perforator is also depicted.
The patient may be marked in either a standing or supine position. The ASIS and the lateral condyle of the femur are marked. For myocutaneous flaps, the design extends from the ASIS to within 8 cm of the lateral femoral condyle. For a myocutaneous flap containing bone, the design is more proximal, overlying the iliac crest and centered on the palpable trochanter.

**Patient Positioning**

An advantage of the TFL flap is that it can be harvested easily in the supine position; this is the preferred position. For some applications, including posterior rotational flaps, the flap may be harvested in a lateral decubitus position, although this is usually not necessary.

**GUIDE TO FLAP DISSECTION**

Once designed, the flap is easily dissected from distal to proximal. After the cutaneous paddle is incised inferiorly, the fascia lata is also incised. It is helpful at this point to suture the skin flap to the fascia to prevent any shearing injuries. The dissection then proceeds easily in the subfascial plane.
The vascular pedicle should be anticipated, starting 12 cm distal to the ASIS, and dissection must proceed more cautiously at this point. At this level one should also look for the lateral femoral cutaneous nerve at the anterior margin of the flap if a sensate flap is desired. The lateral circumflex femoral vascular pedicle is then identified on the deep surface of the muscle and is dissected medially in the plane between the rectus femoris and the vastus lateralis muscles. Any of the branches to the gluteus minimus and vastus lateralis muscles are ligated. Near the origin of the lateral femoral circumflex artery, care must be taken to avoid injury to branches of the femoral nerve. As needed for rotation, proximal musculature can be incised from its origin at the ASIS, and a complete island flap can be created.

**Myofascial-Only Flap**

The myofascial flap is useful when vascularized fascia only is required, such as in an abdominal wall reconstruction. Extension of the fascia lata can be taken with the flap to within a few centimeters of the knee. Because no skin will be taken, access to the muscle is obtained through an incision made at its anterior border, allowing visualization of the vascular hilus. A 10 to 12 cm width of fascia can be carried. Flaps 35 to 40 cm long may be designed.
FLAP VARIANTS

- Myofascial-only flap
- Osteomyocutaneous flap
- Perforator fasciocutaneous flap (lateral circumflex femoral artery–tensor fascia lata perforator flap)

Osteomyocutaneous Flap

The osseous component of the flap, which is a segment of the iliac crest 6 cm long, is supplied by the ascending branch of the lateral circumflex femoral artery and is supplied through the muscle origin.

![Diagram of osteomyocutaneous flap]

**Fig. 12F-6** Osteomyocutaneous design. Note that the design is shifted more proximally than in the standard flap.
This bone can be captured with the flap with muscle only, or with its overlying cutaneous segment. This flap is most commonly used as a free tissue transfer, and often the osteotomies are best performed after dissection and division of the vascular pedicle.

If skin will be carried with this flap, the design should be more proximal and centered over the palpable trochanter, approximately 6 cm below the ASIS.
Perforator Fasciocutaneous Flap

One disadvantage of the TFL flap is that it may be bulky when it carries both skin and muscle components. The TFL skin distribution can be carried as a thin perforator flap based on the perforators that run through the TFL muscle. These vessels are small, and patience and skill are required to follow these vessels through the muscle without injury. When identifying these dominant perforators, the surgeon should keep in mind that they have traveled through the muscle and emerge posterolateral to the central aspect of the muscle. Wide exposure within the muscle is necessary to safely lengthen the pedicle and ligate multiple side branches.

Once the hilum is reached, retraction of the rectus femoris and sartorius muscles help exposure of the origin of the ascending branch of the lateral circumflex vessel, which can be further dissected for more length and diameter. A microdissection technique has been advocated to further thin these flaps and effectively increase pedicle length.

Fig. 12F-7  A, Relationship between the tensor fascia lata muscle and its perforator. The perforator runs in a posterior direction through the tensor fascia lata muscle and emerges at a hiatus in the deep fascia posterolateral to the central portion of the muscle. B, Intramuscular dissection and the course of a perforator of the tensor fascia lata muscle. C, A microdissected thin LCFA perforator free flap. (Courtesy Phillip N. Blondeel, MD.)
ARC OF ROTATION

Myocutaneous Arc

V-Y Advancement Arc
Perhaps the best rotation for trochanteric defects, the V-Y advancement flap places the bulkiest, best-perfused tissues over the area of defect while allowing primary donor site closure.
Anterior and Posterior Arcs of Myocutaneous Flaps
The anterior arc of rotation will cover the abdominal wall, groin, and perineum. The posterior arc of rotation will cover the greater trochanter, ischium, perineum, and with delay, the sacral areas.

Myofascial arc to anterior trunk  Myofascial arc to posterior trunk

Fig. 12F-10

FLAP TRANSFER
Myofascial Flap
Most common indication for this as a pedicle transfer is an abdominal wall reconstruction. The flap is isolated on its vascular pedicle and transferred through a subcutaneous tunnel to the abdominal wall recipient site. In cases of groin defects, direct rotation may be possible without creation of a tunnel.

Myocutaneous Flap
Planning is key when locating the skin flap relative to its need. For more distant needs, the proximal portion of the skin paddle may be deepithelialized or removed. This is best determined by elevating the flap and passing it to its distant site and marking the area of skin need. The flap may be deepithelialized once back on the thigh. For defects within the immediate area, the donor recipient sites can be joined and the flap can be directly rotated. This is commonly performed for groin defects requiring skin. When groin defects include defect in the abdominal fascia, the TFL fascia can be used to patch the defect, negating the need for synthetic mesh closure.

A conservative approach must be taken with both anterior and posterior rotations to leave the dog-ears created by the rotation for later revision. In obese patients, these dog-ears may be significant, and the temptation to revise them immediately should be avoided, because these dog-ears contain valuable blood supply and venous drainage to the flaps. This is an advantage of a V-Y advancement, because no cone of rotation is created.
Free Flap
For osteomyocutaneous and perforator flaps that are used as free flaps, the general principles of reconstruction are followed, including no tension on the pedicle, and in the case of perforator flaps, no tension on the small perforators. A tension-free closure should be the goal.

DONOR SITE CLOSURE
Donor site closure for the TFL rotational or free flap commonly requires the use of skin grafts and is one of the disadvantages of the flap. In select nonobese patients with skin laxity, skin islands of up to 9 cm may be harvested with primary closure. These dimensional principles also apply to flaps taken as free tissue transfer.
CLINICAL APPLICATIONS

This 30-year-old paraplegic man had undergone multiple surgical procedures for decubiti and presented with ischial and sacral decubiti. The large left ischial decubitus was too large for biceps advancement, so a large TFL flap was performed to provide stable coverage of the ischium. The sacral decubiti were excised and closed primarily. The large size of the TFL flap necessitated skin grafting of the donor site.

Fig. 12F-12  A, Preoperative view of the large left ischial decubitus and two small sacral decubiti. The patient is cachectic and has poor soft tissue coverage of bony prominences. B, The sacral wounds are excised and closed. Aggressive debridement of involved ischial skin and ischium were performed, and TFL flap was elevated. The width of the flap was based on the defect, without concern for primary closure of the donor site. C, Flap rotated, providing abundant vascularized tissue for reconstruction. D, Follow-up at 1 month with good take of the skin graft and some areas of secondary healing in the ischium and sacrum. (Case supplied by MRZ.)
This 81-year-old man had a neglected penile squamous cell cancer with bulky metastases to the left groin. The patient stated that he had successfully avoided doctors for more than 40 years. After a total penectomy, bilateral groin lymph node dissections, and creation of a perineal urethrostomy, he had a residual large defect with exposed femoral vessels. He underwent a rotational TFL flap with primary closure of the donor site. For groin defects, it is preferable to connect the donor and recipient sites to facilitate flap placement and to minimize pressure on the vascular pedicle, sometimes seen with tunneled flaps.

**Fig. 12F-13**  
A, Preoperative view of the bulky groin mass to be resected and the penile primary lesion.  
B, Large soft tissue defect with exposed femoral vessels and one half of the scrotal skin with exposed testes. Abdominal fascia was intact.  
C, Flap designed to match the 7 cm skin defect. The flap does not extend beyond the distal third to ensure good skin perfusion.  
D, The flap was easily elevated until it was 12 cm distal to the ASIS, then careful dissection exposed the lateral circumflex femoral pedicle, which was large, and forms the rotation point of the flap.  
E, The flap was rotated and inset without tension. A cone of rotation (dog-ear) is left for future revisions if needed.  
F, Lateral view of the donor site, which was closed primarily. (Case supplied by MRZ.)
This 53-year-old man with a history of STD and condyloma of the penile shaft presented with carcinoma arising from the condyloma, metastatic to the groin bilaterally. After resection of the groin masses, bilateral pelvic lymphadenectomy and partial penectomy, primary closure of the right groin was obtained, but this put tension on the wound on the left side, enlarging it and preventing primary closure. Because of exposure of the lymphatics and femoral vessels and the likelihood that the patient would receive postoperative radiation therapy, it was felt that a skin graft was not a durable solution, so a TFL flap was rotated into the defect. This allowed a tension-free closure, facilitating healing. The donor site was closed primarily.

Fig. 12F-14  A, Preoperative view of condyloma of the penis and bilateral groin masses to be resected. B, Resultant defects of the groin. The midline incision was made for the pelvic lymph node dissection. C, Flap design based on the defect width and length. The flap is centered on the line marked from the trochanter (circle) to the lateral femoral condyle. The anticipated location of the pedicle at 12 cm is also marked. D, Flap dissected.
Fig. 12F-14  E, Flap rotated into the defect. F, Flap inset with primary closure of the donor site. G, Flap inset with all wounds closed. The addition of tissue on the left allowed primary closure on the right. Note the shift of the midline scar. H, The patient is seen 3 months postoperatively after completion of postoperative bilateral radiation therapy to the groin. I, Lateral-oblique view, including donor scar. The cone of rotation persists and does not concern the patient. Revision with liposuction or excision would be delayed up to 1 year after irradiation, and as early as 4 months without radiation therapy. (Case supplied by MRZ.)
This 66-year-old man had a stomal recurrence after undergoing abdominoperineal resection for colon cancer 4 years earlier. A full-thickness wide excision of the abdominal wall and relocation of the stoma were performed. The wound was considered dirty, and prosthetic mesh was thought to be suboptimal for restoring fascial continuity. Autologous fascial repair was performed with a myofascial TFL flap. Ample fascia was available, and the flap easily reached the midabdomen for the repair. Skin carried on the distal third of the flap would have been unreliable without delay, so primary skin closure was achieved by mobilizing local tissue.

Fig. 12F-15  A, Large full-thickness defect of the abdominal wall with resection of left rectus muscle and some oblique musculature and overlying fascia. Peritoneal cavity is exposed. The stoma has been relocated to the right side of the abdomen. B, The entire TFL flap with associated fascia was elevated as a myofascial unit without skin. Elevation stopped proximally at the lateral circumflex femoral pedicle, which was spared. C, The flap is rotated and passed through a subcutaneous tunnel to the recipient site. Repair of the fascial defect is performed with the autogenous fascia using a permanent suture. D, Primary closure is obtained at all sites. Because the distal skin of a TFL is unreliable, abdominal skin mobilization was favored for closure of the skin defect. (Case supplied by MRZ.)
This 28-year-old paraplegic man presented with a stage IV trochanteric pressure ulcer. After he was prepared for surgery with nutritional supplementation and local dressing changes, he underwent retroposition V-Y TFL flap closure of his wound. No pressure was allowed on the flap for the first 4 weeks.

Fig. 12F-16  A, The wound on the day of surgery. There is always an associated bursa (*dotted line*), and all thin skin covering the bursa should be resected before planning the flap dimensions, because the dead space needs to be filled to prevent recurrence. The flap design and the anticipated location of the vascular pedicle are shown. B, Proper debridement precedes all concerns about the flap. Here thin overlying skin, bursa, and prominent bone have been aggressively resected. C, The flap easily slides posteriorly to fill the defect and provide adequate skin coverage. The donor site is closed primarily, supporting the flap advancement. D, Two months postoperatively, the patient’s wounds are healed and there is extra padding to the trochanteric area to prevent recurrence. (Case supplied by MRZ.)
The safest method for extending the size of the LCFA perforator flap is to dissect and include simultaneously the neighboring perforators for adjacent flaps. By including perforators derived from both the ascending and descending branches of the lateral circumflex femoral artery, and with the superficial circumflex femoral artery, an immense flap can be elevated safely, encompassing almost the entire anterior thigh, as with this 49-year-old man with deep peripatellar burns.

Fig. 12F-17  A and B, After the requisite debridement, the patella and quadriceps tendon were exposed. C, A combined composite LCFA–TFL perforator flap, groin flap, and LCFA–vastus lateralis perforator flap was planned to include a portion of the iliotibial tract. D, Undersurface of this megaflap. The perforator from the descending branch of the lateral circumflex femoral vessels (lower right) had to be divided to preserve the motor nerve to the TFL muscle, and then reanastamosed to itself. The superficial circumflex femoral vessels (upper middle) were anastomosed to the ascending branch of the lateral circumflex femoral vessels (lower middle). The common trunk of the lateral circumflex femoral vessels was anastomosed to the medial sural artery and vein at the recipient site. E, The knee extended and F, flexed, 3 years later. (Case courtesy Phillip N. Blondeel, MD.)
Pearls and Pitfalls

• Sacrifice of the TFL muscle produces minimal functional loss in ambulatory patients but should be avoided in high-performance athletes.
• Extended TFL flaps can be created using delay procedures, greatly increasing the skin territory carried with the flap.
• A vascularized osseous segment can be carried with the flap, but is a distant fourth or fifth choice to the other common osseous flaps (fibula, DCIA, scapula, radius).
• The flap can be used as a sensate flap, which gives it advantages over other nonsensate options.
• Pedicle location is consistent and can be dissected in a supine position, facilitating a two-team approach to reconstruction.
• The flap may be bulky in some patients; this can be reduced by removing some of the muscle superiorly or harvesting the flap as a perforator flap.
• Excessive thinning of the subcutaneous tissue using microdissection techniques may injure the lateral femoral cutaneous nerve supplying the flap. Similar skin territory without associated bulk can be obtained using the ALT flap and larger muscle bulk and fascia can be carried with the rectus femoris flap. These alternatives should be considered, depending on the reconstructive need.

EXPERT COMMENTARY
Michael R. Zenn

Indications
The TFL is a workhorse flap for the reconstructive surgeon for defects of the thigh and groin. It is the flap of choice for trochanteric decubiti and for groin defects after radical lymph node dissections for various cancers.

Advantages and Limitations
The advantages of the TFL flap lie in its availability, its generous source of fascia and skin, and its minimal morbidity. That said, there are always choices between the TFL and other nearby flaps, such as the ALT, rectus femoris, gracilis, and rectus abdominis, so individualization for each clinical case is important.

Recommendations
Planning
The reason the TFL is the flap of choice for trochanteric decubiti relates to the natural history of decubitus patients and the location of the TFL. Decubitus patients are “patients for life” and will have multiple decubiti over time; this needs to be considered in operative planning. Use of the TFL for a trochanteric defect, the biceps femoris and gracilis for an ischial defect, and gluteal flaps for a sacral defect serves the patient best for lifetime reconstructive planning and having enough tissue available to reconstruct future defects.

Continued
**Technique**

As for the favored technique of TFL use for trochanteric decubiti, the retroposition V-Y advancement flap (see Fig. 12F-16) is superior to simple rotation flap for a few reasons. First, the TFL flap is bulky proximally and quite thin distally. This is fine for resurfacing the groin, but for decubiti, bulk is required for successful, durable reconstruction. The retroposition V-Y TFL places the bulkiest tissues into the defect. Second, by crafting the muscle as a V-Y flap, primary closure of the donor site is accomplished, avoiding one of the biggest drawbacks of the flap: the need to skin graft the donor site. It is critical, as it is for all flaps for decubiti, to design the flap large enough so recurrences can be dealt with by reelevation and advancement of the flap.

**Complications**

The main complications relating to use of the TFL flap are donor site cosmesis, areas of tissue excess require revision, seroma formation, and inadequate tissue to perform the reconstructive task. The most common complaint of patients who have had TFL flaps is the large skin graft that is required at the donor site. Although this can be hidden in clothes, they still do not like it. Using the retroposition flap for trochanteric wounds avoids this deformity. For other uses, a skin graft is still required for flaps greater than 9 cm in width. The dog-ear created by rotating the TFL flap can be significant. I do not recommend revising it for at least 4 to 6 months, because it contains the blood supply to the flap.

Much of the deformity may settle over time, and resection of the dog-ear at 4 to 6 months will not endanger the blood supply to the flap. It is important to use a large-bore drain in this area as there are surrounding lymphatics that contribute to postoperative seromas. Drains may be left in for 2 to 3 weeks in some cases. Although touted as vascularized fascial replacement for abdominal wall reconstruction, the flap may fall short in providing adequate surface area, and the use of synthetic mesh should be considered.

**Bibliography With Key Annotations**


Various common locations of pressure sores require specific considerations. The most commonly used flap for the treatment of trochanteric ulcers is the tensor fascia lata (TFL) flap. The authors noted that in their experience with the original flap, excessive tension and eventual suture separation at the confluence of the donor site flaps and the TFL flap are the most common problems. They presented a new design for the TFL flap for the coverage of trochanteric pressure sores. An anterior triangular extension was designed exactly at a point where the flaps that will cover the donor site unite after transposition. The deepithelialized proximal part of the flap is folded into the pouch and sutured. The “duck” flap was applied to 31 trochanteric pressure sores in 27 patients with no major complications. This modification has many advantages: the flap is reliable and easily designed; formation of dead space and a cone-shaped dog-ear deformity resulting from rotation is prevented; better aesthetic results are achieved; suture separation is prevented with a tension-free closure; the deepithelialized part produces a tight attachment of the flap to the recipient bed; and because no muscle tissue is included, the flap is more resistant to pressure.


The use of the tensor fascia lata was first described as a rotation or island flap and evolved into a free flap in the late 1970s. This series of 85 patients undergoing free TFL transfer included complex...
head and neck, abdominal wall, and lower limb reconstruction. The overall success rate was 93% (79 patients), partial flap loss, 5% (four cases), and flap failure, 2% (two patients). Twelve patients required unplanned return to the operating room for exploration, resulting in a 75% salvage rate.


The authors reported their experience with a method for definitive abdominal wall reconstruction using the free tensor fascia lata myofasciocutaneous flap anastomosed to the intraperitoneal gastroepiploic vessels. This is a single-stage reconstruction capable of reconstructing reliably a full-thickness defect involving any region of the abdominal wall. The fascial component of the flap reconstructs the abdominal wall with like tissue, and the cutaneous portion of the free TFL provides a durable and aesthetically acceptable external cover. The intraperitoneal gastroepiploic artery and vein were the first-choice recipient vessels used in three patients. These intraperitoneal recipient vessels allow uninterrupted fascial closure, restoring structural integrity to the abdominal wall, and allow the use of free flaps with short vascular pedicles.


Free tissue transfer is an essential part of head and neck reconstruction. Despite several flap options, free perforator flaps have become very popular for head and neck. The anterolateral thigh perforator flap has multiple advantages among other options and is preferred by most reconstructive microsurgeons. Despite its advantages, sometimes it is impossible to harvest an ALT perforator flap, and the surgeon has to select another option. Between January 2002 and June 2005, five TFL perforator flaps were used for head and neck reconstruction because an ALT perforator flap could not be elevated because of the absence of or insufficient myocutaneous perforators. Only one flap was reexplored and salvaged by redoing the venous anastomosis. All flaps survived with no other problems. Donor sites were covered by split-thickness skin grafts in four patients and closed primarily in one. Doppler examination is important in planning the ALT perforator; if the signals of the perforators are absent or very weak, the surgeon can shift to another flap. This decision may also be made during the operation when insufficient perforators are seen. The authors stated that the tensor fascia lata perforator flap is a safe alternative when anterolateral thigh perforator harvest is not possible. The TFL perforator flap can be harvested from the same anatomic region with almost the same morbidity.


The aim of this short report about the main source of the tensor fascia lata flap (as a muscular, myocutaneous, or perforator flap) was to invite surgeons to exercise caution during the deep dissection of the pedicle, because its vascular supply presents a higher variability than previously reported.


The authors presented their experience in functional reconstruction of the Achilles tendon with large tissue defects after trauma and infection. To cover the skin defect and reconstruct the Achilles tendon, they used the free TFL flap. From 1997 to 2003 six men, ranging from 22 to 71 years of age (average 38.6 years), underwent this reconstructive procedure. All of them had sustained a traumatic loss of the tendon and the overlying tissue. After initial debridement, the reconstruction with a TFL free flap was performed. To achieve a strong distal fascia lata attachment to the calcaneal bone, the authors developed a special method of fixation. After vertical osteotomy in the calcaneus, the distal part of the fascia flap was introduced between the bone segments, which were fixed together with a spongiosa screw. For functional outcome, it was important to fix the foot in a 90-degree position, with tension on the vascularized fascia lata. The range of motion of the ankle of the reconstructed foot showed 93.7% in comparison to the normal foot. No flap failure occurred in any of the six patients.
Simultaneous soft tissue and function restoration of the foot with TFL free flap is an optimal one-stage reconstructive procedure.


The authors reviewed techniques for autologous repair of abdominal wall defects that could not be closed primarily. Medline and PubMed were searched for English or German publications using the following keywords: components separation technique (CST), Ramirez, da Silva, fascia lata, tensor fascia lata, latissimus dorsi, rectus femoris, myocutaneous flap, (auto)dermal graft, dermoplasty, cutisplasty, hernia, abdominal wall defect, or combinations thereof. Publications were analyzed for methodological quality, and data on surgical technique, mortality, morbidity and reherniation were abstracted. The CST is the best documented procedure; it is associated with a high morbidity rate of 24% and a recurrence rate of 18.2%. Although the results of the da Silva technique are good (morbidity 5% to 20% and reherniation 0% to 3%), the poor methodologic quality of the studies precludes firm conclusions. Repair with free fascia lata or dermal grafts is an alternative if the above techniques cannot be used, but wound complications affect 42% of patients and recurrent hernia up to 29%.

Pedicled or free vascularized flaps are reserved for complex situations.


The tensor fascia lata flap is one of the appropriate choices for the coverage of trochanteric pressure sores. The authors designed a new hatched-shaped TFL myocutaneous flap with distal Z-plasty closure and applied it to four trochanteric defects in four patients. Satisfactory results were obtained in all patients. The hatchet-shaped TFL myocutaneous flap is very safe, reliable, and practical. Designing the flap in a hatchet shape allows one to use the proximal and well-vascularized portion of the flap in the trochanteric pressure sore area. Another important advantage is the possibility of reuse resulting from recurrence. Prevention of a “dog-ear” deformity at the recipient site provides a smooth contour on the lateral aspect of the thigh. Another advantage is the tension-free Z-plasty closure of the donor site without the need for grafting.


The vascular supply of the tensor fascia lata flap and of the lateral thigh skin was studied in 10 cadavers to evaluate whether the lateral thigh skin toward the knee could be incorporated into an extended TFL flap. Within each cadaver, vascular injection of radiopaque material preceded flap elevation in one limb and followed flap elevation in the contralateral limb. Flaps raised after vascular injection were examined radiographically to evaluate the vascular anatomy of the lateral thigh skin independent of flap elevation. On vascular injection into the profunda femoris, the upper two thirds of the flaps was better visualized than the distal third. On injection into the popliteal artery, the vasculature of the distal third of the flaps was better visualized. Flaps raised before vascular injection were examined radiographically to delineate the anatomical territory of the vascular pedicle that had been injected. In these flaps, consistent cutaneous vascular supply was seen only in the skin overlying the TFL muscle, confirming that myocutaneous perforators are the predominant means by which the pedicle of the TFL flap supplies the skin of the lateral thigh. Extended TFL flaps were elevated bilaterally in one cadaver, and selective methylene blue injections were made into the lateral circumflex femoral artery on one side and into the superior lateral genicular artery on the contralateral side. Methylene blue was observed in the proximal and distal thirds of the skin paddles, respectively, leaving unstained midzones. The vascular network of the lateral thigh skin could be divided into three zones. The lateral circumflex femoral artery and the third perforating branches of the profunda femoris artery perfuse the proximal and middle zones of the lateral thigh skin, respectively. The superior lateral genicular artery branch of the popliteal artery perfuses the distal zone. The middle and distal zones meet 8 to 10 cm above
the knee joint, where the skin paddle of the TFL flap becomes unreliable. These data indicate that if the aim is to incorporate the skin over the distal thigh in an extended TFL flap without resorting to free tissue transfer, then either a carefully planned delay procedure or an additional anastomosis to the superior lateral genicular artery is required.


The use of prosthetic mesh has revolutionized the repair of ventral hernias; however, the occurrence of infection related to its use remains a notable complication that may result in fistula formation of the skin or intestine, sepsis, or recurrence of ventral hernia. The authors presented two cases in which the pedicled TFL flap was effective as a treatment for infected large abdominal hernias. Two men aged 61 and 78 years old underwent a ventral hernia repair using Composix Kugel mesh. They both developed a wound infection with methicillin-resistant Staphylococcus aureus. Conservative therapy was not successful, and the defect in the abdominal wall of the two patients measured 12 by 21 cm and 7 by 10 cm in length, respectively. Reoperations were performed to remove the infected mesh and reconstruct the abdominal wall with a bilateral and a left-side pedicled TFL flap, respectively. No recurrence of the ventral hernia has been seen in 30 months and 7 months of follow-up. A review of previous studies showed that no patients treated with a pedicled TFL flap experienced a recurrent hernia. Therefore the pedicled TFL flap was considered to be effective for infected large abdominal recurrent hernia.


The authors conducted a study to differentiate between myocutaneous and septocutaneous perforators of the tensor fascia lata perforator flap; to evaluate their number, size, and location; and to provide landmarks to facilitate flap dissection. An additional injection study estimated the skin area of the flap. The anatomic study was performed on 23 fixed and injected cadavers. The injection study was performed on 10 fresh cadavers. On one side, the ascending branch of the lateral circumflex femoral artery was injected with methylene blue; on the other side, the septocutaneous perforators were injected selectively. The size, location, and borders of the stained skin were measured in both studies. Forty-five thighs were included in the study. All perforators emerged from the ascending branch of the lateral circumflex artery. The average number of myocutaneous perforators was 2.3 (range 0 to 5), the distance from the anterior superior iliac spine was 10.9 cm (range 4.5 to 16.1 cm), and the diameter was 0.9 mm (range 0.2 to 2 mm). Four specimens had no myocutaneous perforator. The average number of septocutaneous perforators was 1.8 (range 1 to 3), the distance from the anterior superior iliac spine was 10.9 cm (range 6.2 to 15.7 cm), and the diameter was 1.5 mm (range 0.5 to 3 mm). Seventy-six percent of the septocutaneous perforators emerged between 8 and 12 cm from the anterior superior iliac spine. The possible pedicle length of a flap based on these vessels was 8.1 cm (range 6.5 to 10 cm). In the injection study, the average skin area stained with methylene blue was 19.4 by 13.4 cm (range 10 to 24 cm by 7 to 17 cm) in the ascending branch group. In the perforator group, the average skin area was 19.2 by 13.7 cm (range 15 to 22 cm by 12 to 16 cm).


The method most frequently used for the coverage of trochanteric pressure sores is the TFL flap. The authors described a hatchet-shaped incision strategy for the TFL flap, which preserves the safe blood supply of the flap and keeps the flap mobile enough. The part of the flap including the muscle is adapted to the greater trochanter. This provides a good aesthetic result without dog-car formation at the rotation point of the flap. The donor site is closed in V-Y fashion; the closure does not require any skin grafting or designing a local flap. The TFL hatchet flap was used nine times on eight patients to cover trochanteric pressure sores. With one exception all patients healed. No recurrence was observed during the follow-up period, and no contour difference developed on the lateral aspect of the thigh.

A new method, called “microdissection,” has been introduced to create a thin flap by elevating the tensor fasciae latae perforator flap to serve as a microdissected thin TFL perforator flap. In microdissection, perforators that run in the posterolateral direction in the adipose tissue after penetrating the deep fascia are dissected meticulously using an operative microscope, and a thin flap is elevated in a single process. The caliber of the perforator artery and vein in the TFL muscle measures approximately 0.7 mm and 0.9 mm, respectively. When transplanting the flap, an end-to-side anastomosis to the main artery measuring 1 to 2 mm is preferable to avoid the risk of arterial thrombosis. In contrast, an end-to-end anastomosis of the perforator vein to the comitans vein of the main artery can be performed safely. In this study, 11 flaps were transplanted to the sites of skin defects of the neck, hand, axilla, knee, and foot. The author stated that the first clinical indication of this flap is reconstruction of hand skin defects.


In the three cases presented in this study, free TFL perforator flaps were used successfully for the coverage of defects in the extremities. This flap has no muscle component and is nourished by muscle perforators of the transverse branch of the lateral circumflex femoral system. The area of skin that can be nourished by these perforators is larger than 15 by 12 cm. The advantages of this flap include minimal donor site morbidity, preservation of motor function of the TFL muscle and fascia lata, the ability to thin the flap by removing excess fatty tissue, and a donor scar that can be concealed. In cases that involve transection of the perforator above the deep fascia, the operation can be completed in a very short period of time. This flap is especially suitable as a free flap for young women and children who have scars in the proximal region of the lateral thigh or groin region that were caused by split-thickness skin grafting or full-thickness skin grafting during previous operations.


Microsurgical free flap surgery has progressed from simply providing wound coverage to restoring a high level of function. The concepts and practice of using compound, composite, and chimeric flaps have recently further enhanced the versatility of free flaps in reconstructive surgery. A lateral circumflex femoral arterial (LCFA) system can provide a potential single composite free tissue transfer for restoration of functional and structural integrity. Between 1997 and 2003, the authors used 44 free flaps to restore functional and structural defects in the lower limbs. The versatility of the LCFA system allowed utilization of the anterolateral thigh, vastus lateralis, tensor fascia lata, rectus femoris, and iliac crest. Combinations of tissues from this system were employed to restore defects in the patellar tendon (14), Achilles tendon (13), extensor hallucis tendon (2), anterior compartment with/without lateral compartment muscle (11), anterior compartment muscle and segmental tibial bone (3), and composite calcaneus (1). The free flap success rate was 97.7%. Four reexplorations were performed, with one subsequent failure. Eight patients developed wound infections, of which two required secondary amputations, resulting in a limb salvage rate of 95.4%.


Pressure sores in the ischial and the trochanteric regions are usually encountered in long-term bedridden and wheelchair-dependent patients. A number of techniques have been developed for the reconstruction of pressure sores. The tensor fascia lata myocutaneous flap has been extensively employed to close the trochanteric defect. Despite the utility of its having a constant pedicle and proximal bulky muscle, the relative shortness of the flap and insufficient padding in the distal portion limit the applications for distant locations of pressure sores. From January 2001 to December 2003, eight patients with ischial...
and trochanteric pressure sores underwent TFL flap reconstruction in combination with a tangentially split vastus lateralis muscle. The descending branches of the lateral circumflex femoral arteries were also included in these flaps. All of the procedures have been successful, and no flap necrosis has been observed. Sufficient bulk of the flap and reliable distal skin paddle constitute the advantages of this flap.


A 46-year-old patient sustained a dia-infracondylar tibial fracture from a ski accident. Open reduction and internal fixation (ORIF) was carried out. After an initially uneventful postoperative course the patient was readmitted because of local and systemic infection signs. Radical surgical debridement was carried out followed by VAC therapy. The resulting defect consisted of bone defect of the tibia tuberosity, and complete loss of the patellar tendon and the overlying soft tissue. Reconstruction was carried out with a combined TFL flap including the TFL muscle with the iliotibial tract, the vascularized part of the iliac crest, and the overlying soft tissue. Bone healing took place without signs of osteomyelitis recurrence, and full weight-bearing was possible 4 months after reconstruction. Successful reconstruction of the patellar tendon using the iliotibial tract enables the patient to have full active knee joint motion. The soft tissue coverage was stable. The donor site showed inconspicuous healing without pain and normal range of motion of the hip joint. This composite TFL flap is an interesting flap not only for defects following trauma, but also for combined defects following extensive infections after knee implants.
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>Largest of the quadriceps group of muscles, the vastus lateralis occupies two thirds of the surface area of the lateral thigh. It extends from the proximal femur to the patella between the vastus intermedius and biceps femoris muscles and beneath the tensor fascia lata.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>10 × 26 cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>Intertrochanteric line, greater trochanter, gluteal tuberosity, and lateral intermuscular septum.</td>
</tr>
<tr>
<td>Insertion</td>
<td>Superior patella.</td>
</tr>
<tr>
<td>Function</td>
<td>It is a strong leg extensor muscle.</td>
</tr>
<tr>
<td>Composition</td>
<td>Muscle.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type I.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Descending branch of the lateral circumflex femoral artery.</td>
</tr>
<tr>
<td>Minor Pedicles</td>
<td>Transverse branch of the lateral circumflex femoral artery; posterior branches from the profunda femoris artery; superficial branch of the lateral superior genicular artery.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td>Motor: Muscular branch of the femoral nerve.</td>
</tr>
</tbody>
</table>
Section 12G

THIGH

Vastus Lateralis Flap

CLINICAL APPLICATIONS

Regional Use
- Groin
- Perineum
- Trochanter
- Ischium
- Knee
- Abdomen

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Hip defects
ANATOMY OF THE VASTUS LATERALIS FLAP

**Fig. 12G-1**

**Dominant pedicle:** Descending branch of lateral circumflex femoral artery

**Minor pedicles:** Transverse branch of lateral circumflex femoral artery; posterior branches from profunda femoris artery; superficial branch of lateral superior genicular artery
ANATOMY

Landmarks
The vastus lateralis muscle occupies two thirds of the surface area of the lateral thigh. It is bisected by the iliotibial tract on its surface. The muscle extends from the proximal femur to the patella. It is located between the vastus intermedius and biceps femoris muscles and lies beneath the fascia lata.

Composition
Muscle. When skin is required, this flap can be carried in combination with the skin of the anterolateral thigh (ALT) or the skin of the tensor fascia lata (TFL) flap.

Size
10 × 26 cm.

Origin
Anteriorly, the vastus lateralis originates from the greater trochanter and the intertrochanteric line. Posteriorly, it originates from the intermuscular septum and the gluteal tuberosity.

Insertion
Inserts into the patella with the tendon of the rectus femoris.

Function
A strong leg extensor as well as a lateral knee stabilizer. Its function is expendable if the rectus femoris and tensor muscles are intact.

Arterial Anatomy (Type I)

Dominant Pedicle

*Descending branch of the lateral circumflex femoral artery*

**REGIONAL SOURCE** Profunda femoris artery.
**LENGTH** 4 cm.
**DIAMETER** 1.5 mm.
**LOCATION** Superior third of the muscle, extending along the medial border of the muscle.

Minor Pedicle

*Transverse branch of the lateral circumflex femoral artery*

**REGIONAL SOURCE** Profunda femoris artery.
**LENGTH** 3 cm.
**DIAMETER** 1 mm.
**LOCATION** Transverse branch of the lateral circumflex femoral artery enters the muscle in the superior fourth of the muscle from its posterior surface.

Minor Pedicle

*Posterior branches from the profunda femoris artery*

**REGIONAL SOURCE** Profunda femoris artery.
**LENGTH** 1 to 2 cm.
**DIAMETER** 0.4 mm.
**LOCATION** Inferior half of the muscle at the lateral intermuscular septum.

Minor Pedicle

*Superficial branch of the lateral superior genicular artery*

**REGIONAL SOURCE** Popliteal artery.
**LENGTH** 3 cm.
**DIAMETER** 0.5 mm.
**LOCATION** Superficial branch of this pedicle supplies the distal muscle from the area of the lateral condyle of the knee.

Venous Anatomy

Venae comitantes accompany the dominant pedicle and minor pedicles. Both the descending and transverse branches of the lateral circumflex femoral vein empty into the lateral circumflex femoral vein, which has a diameter of 2.5 mm as it joins the femoral vein. The superficial branch of the lateral superior genicular vein drains into the popliteal vein.
Nerve Supply

Motor: Muscular branch of the femoral nerve. The motor nerve enters the proximal muscle at the medial border inferior and adjacent to the lateral circumflex femoral vessels.

Vascular Anatomy of the Vastus Lateralis Flap

**Closeup view of major and minor pedicles supplying flap**

**Deep surface of flap**

**Radiographic view**

Fig. 12G-2

Dominant pedicle: Descending branch of lateral circumflex femoral artery \( (D) \)

Minor pedicles: Transverse branch of lateral circumflex femoral artery \( (m_1) \); posterior branches from profunda femoris artery \( (m_2) \); superficial branch of lateral superior genicular artery \( (m_3) \)
FLAP HARVEST

Design and Markings
For muscle harvest, an incision is made directly overlying the vastus lateralis muscle on a line from the greater trochanter to the lateral patella.

Patient Positioning
The patient is placed in the supine or lateral decubitus position.
GUIDE TO FLAP DISSECTION
The skin incision is deepened through the fascia lata, which will include the medial edge of the tensor fascia lata muscle proximally and the iliotibial tract distally. The rectus femoris muscle is then retracted medially to expose the vastus lateralis muscle.

Fig. 12G-4  A, Initial exposure reveals the dominant vessels as they enter the undersurface of the vastus lateralis muscle after passing beneath the rectus femoris muscle.

Posteriorly, the lateral margin of the muscle is formed by the lateral intermuscular septum. The muscle fibers of insertion are then divided and the muscle is elevated from distal to proximal. Contributions from the superior lateral genicular artery and vein are ligated.

Fig. 12G-4  B, The vastus lateralis muscle is elevated away from the vastus intermedius muscle. The two muscles are still attached by numerous deep muscular perforators, which are ligated.
During elevation, care is taken to visualize and preserve the descending branch of the lateral circumflex femoral vessels that enter the medial aspect of the vastus lateralis. The muscle is elevated to the level of the greater trochanter. Separation from the vastus intermedius is required, because the border is often indistinct and must be arbitrarily determined. The flap can be used for transposition at this point, or the origin can be divided, giving further mobility to the flap.

**FLAP VARIANTS**

- Vastus lateralis combined with ALT flap (see Section 12A)
- Vastus lateralis combined with TFL flap (see Section 12F)
- Distally based flap

**Distally Based Flap**

The distal part of the muscle can be elevated based on its minor pedicle, the superior lateral genicular artery, and veins that enter the distal posterior muscle belly. After the muscle is exposed between the greater trochanter and the lateral condyle of the femur, the muscle is separated from the vastus intermedius medially and the biceps femoris posterior laterally. After deciding the amount of muscle needed for reconstruction, the muscle is divided and elevated from proximal to distal. Skeletonization of the pedicle is not recommended; rather, a few centimeters of muscle attachment should be maintained superior to the lateral condyle of the femur. The entire muscle cannot be elevated on this pedicle.
**ARC OF ROTATION**

**Standard Flap**

The standard flap can reach the trochanter, ischium, acetabular fossa, groin, perineum, lower abdomen, and posterior iliac crest. The distally based flap can be rotated to the knee.

**FLAP TRANSFER**

The flap is transposed directly into the defect to be reconstructed or passed through a tunnel. If there has been previous groin dissection and irradiation, this may not be possible, and the contralateral flap or another flap should be chosen.

**FLAP INSET**

The fascial component of the flap should be used to advantage and sutured into the bed at the recipient site. There should be no tension on the pedicle or any areas of compression.

**DONOR SITE CLOSURE**

Primary closure of the skin should be obtainable, because skin is not taken with the flap. When taken as part of the ALT or TFL flaps, closure should be guided by principles of these flaps.
CLINICAL APPLICATIONS
This 72-year old woman had recurrent squamous cell carcinoma of her scalp. A free vastus lateralis muscle flap was utilized to reconstruct the defect.

Fig. 12G-6  A, The defect measured 10 by 12 cm. B and C, A vastus lateralis (VL) muscle flap measuring 11 by 16 cm was harvested from her right thigh. The recipient vessels were the superficial temporal vessels. D and E, Split-thickness skin grafts over the muscle flap are well healed 3 weeks postoperatively. (Case courtesy Peirong Yu, MD.)
This 75-year-old man presented with recurrent cancer in the pelvis. He had undergone chemoradiation and abdominoperineal resection for a rectal cancer.

**Fig. 12G-7**  
A. A total pelvic exenteration was performed, with exposed, irradiated iliac vessels.  
B and C. The left vastus lateralis muscle was raised as an island flap and tunneled under the groin skin to the pelvis to cover the iliac vessels and obliterate the pelvic dead space.  
D. Six months later left groin metastasis was noted. Radical groin dissection was performed, with exposed, irradiated femoral vessels. A colostomy and urostomy were present in the abdomen, and the rectus femoris vascular pedicle had already been sacrificed; therefore the contralateral right vastus lateralis muscle was raised as an island flap.  
E. The flap was tunneled under the suprapubic skin to reach the left groin.  
F. The area has healed uneventfully. (Case courtesy Peirong Yu, MD.)
Pearls and Pitfalls

- With the adjacent thigh muscles intact (TFL, rectus femoris), the vastus lateralis muscle is expendable, and few functional deficits result from its harvest.
- This flap can deliver a large volume of muscle for deep defects of the hip, femur, and groin.
- The flap shares the advantages of the ALT for free tissue transfer with a long pedicle with good proximal vessel diameter, but it is easier to dissect, because no intramuscular dissection is required.
- The vastus lateralis muscle flap is seldom used for abdominal wall reconstruction, because it is quite difficult to elevate, and other flaps such as the rectus femoris or TFL offer more fascia.
- The donor site is subject to prolonged drainage; drains should be left in place until the discharge subsides.
- If not required for reconstruction, it is prudent to leave the distal third of the muscle intact. This avoids the bloody and imprecise dissection of the vastus lateralis where it is fused with the vastus intermedius and biceps femoris muscles.

EXPERT COMMENTARY

Peirong Yu

Indications
In addition to the indications described in the chapter, I have used this flap for reconstruction of pelvic exenteration defects to provide volume, for scalp reconstruction, and for other areas when a muscle is needed.

Flap Selection
The advantages of the vastus lateralis muscle flap include low donor site morbidity and maintaining the patient in one position. It competes with the commonly used latissimus dorsi and rectus femoris muscle flaps. Compared with the latissimus dorsi muscle, the vastus lateralis muscle is smaller. Therefore the size of the defect should be carefully evaluated before considering the vastus lateralis muscle. If the patient is already in a lateral position, the latissimus dorsi flap is the first choice. If the patient is in the supine position and the defect is small enough to be covered by the vastus lateralis muscle, then this muscle would be my first choice to avoid a position change and repreparation.

The vastus lateralis muscle is larger than the rectus femoris muscle. In most cases, either flap is fine. However, in patients with limited pulmonary reserve (for example, patients with COPD), avoiding an abdominal incision required for harvesting the rectus abdominis muscle flap may be important. On the other hand, in young and athletic patients, especially runners, sacrificing the vastus lateralis muscle may cause symptomatic weakness in the leg. The gracilis muscle is much smaller than the vastus lateralis muscle and, therefore, not suitable for larger defects.

Continued
Flap Dissection

My preferred approach to harvest the vastus lateralis muscle flap is the anterior approach. With the patient in the supine position, a line is drawn to connect the anterior superior iliac spine and the supralateral corner of the patella, as for an ALT flap harvest. An incision is made directly on this line and carried down to the deep fascia. Once the fascia is opened, the intermuscular space between the vastus lateralis muscle and the rectus femoris muscle should be in view. This intermuscular space is entered, and the vascular pedicle to the vastus lateralis muscle, the descending branch, is visualized (Fig. 12G-8). Next, the descending branch is dissected off the vastus intermedius fascia, starting from its medial edge. Once the blood vessels are off the fascia, the vastus lateralis muscle can be quickly detached from the vastus intermedius fascia in a medial to lateral direction (Fig. 12G-9).

Donor Site Morbidity

The donor site morbidity of the vastus lateralis muscle has not been extensively studied. In our study with the ALT flap, we have found that fewer than 10% of the patients complained of leg weakness when less than half of the vastus lateralis muscle was harvested. When the entire vastus lateralis muscle was harvested, 25% of the patients complained of leg weakness, which typically lasted 3 to 6 months. Other complaints included difficulties climbing stairs, occasional instability of the knee joint, and seroma formation. When this flap is used for pelvic reconstruction after pelvic exenteration, patients are usually overwhelmed by the major abdominal surgery, and the leg donor site is unnoticed.
**Bibliography With Key Annotations**


Distally based vastus lateralis muscle flaps can be performed as a salvage procedure for repeated soft tissue defects around the knee. An advantage of this flap is that it does not require microsurgical anastomosis. The authors presented four cases of knee reconstruction with this flap. Three were in the setting of total knee arthroplasty revision, and one was performed after a posttraumatic knee amputation. Skin closure was achieved in all cases, although distal marginal necrosis occurred in two. Final joint mobility was consistently poor. Details of the technique were described.


Lateral circumflex femoral artery (LCFA) system flaps are effective for skull base reconstruction, because they provide flap design versatility, adequate tissues to fill dead space, vascularized fascia to augment dural repairs, and a very long pedicle. The authors reviewed results of 20 LCFA system free flaps for cranial base reconstruction performed at a tertiary center. The defects resulted either from resections of primary or recurrent neoplasms or from secondary problems after cranial base surgery. The types of flap transferred were: combinations of anterolateral/anteromedial thigh flaps with vastus lateralis muscle or TFL flaps (8); anterolateral fasciocutaneous flaps (6), and muscle/myocutaneous flaps (6). Nineteen of 20 flaps were successful. One patient died postoperatively, and one patient had a myocardial infarction. Minor complications included partial flap loss (1), temporal CSF leaks (2), two donor site hematomas, minor wound breakdowns (2), facial nerve weakness (3), and donor site numbness (4). One patient had local recurrence and underwent successful ablative surgery, followed by a forearm free flap.


To better understand how the anatomy of the vastus lateralis motor nerve affects ALT flap harvest, the authors reviewed 43 ALT flap procedures. In three cases, the course of the motor nerve to the muscle significantly modified the flap harvest. In one case, the motor nerve passed between the ve- nae comitantes of the descending branch of the lateral femoral circumflex artery, just proximal to the midperforator origin. In two cases, large skin islands were raised with two perforators included in each flap. The motor nerve passed between the two perforators in these cases. The authors concluded that two patterns of nerve anatomy could negatively affect ALT flap elevation. In one pattern, the nerve passes through the main vascular pedicle. In the other pattern, the motor nerve passes between the multiple perforators required for large flaps.


In a series of 12 patients, the authors demonstrated the utility of the extended-pedicle free vastus lateralis muscle flap for lower extremity soft tissue reconstruction. This flap has a long pedicle with a large caliber, low donor site morbidity, and versatile shape and volume. They included a segment of the distalmost part of the muscle, distal to the entry point of the motor nerve to the vastus lateralis, based on the descending branch of the lateral femoral circumflex vessels. The vascular pedicle was 20 cm or less, with a large caliber. All flaps were successful.


The authors reconstructed cranial base defects in seven patients using a free vastus lateralis muscle flap. In two cases, a vastus lateralis flap incorporated the ALT skin as a myocutaneous flap. In four cases, a free flap was indicated after tumor ablation. In three cases, a free flap was indicated for wound complications or CSF leakage following cranial base surgery. All flaps were successful. The indications and advantages of this flap were discussed.


To demonstrate the effectiveness of pedicled muscle flaps for treating recalcitrant joint infections after total hip replacement, the authors treated 24 patients with either a pedicled rectus femoris or a vastus lateralis muscle flap. The mean patient age was 67.4 years. The mean number of attempts to close the wound was four. Twenty rectus femoris and five vastus lateralis flaps were used. One of each type failed, requiring revision. At 47 months (mean follow-up), 22 patients had a healed wound, and 2 had a persistent sinus. The prosthesis had been retained in 5 patients. It had been removed in all others and subsequently reimplanted in 9 patients. At the final follow-up, 6 patients were still taking antibiotics. Because of the numerous previous debridements, the authors recommended transferring these flaps earlier.


This article focused on the authors’ attempt to treat 10 patients who had challenging infections in the hip area using a modified vastus lateralis flap transposition. The flap was chosen for its simple design and ability to provide soft tissue coverage and dead space filler. All patients had had repeated failed operations, including debridement, implantation of antibiotic-loaded cement spacers, and fasciocutaneous flap transposition. The flaps were performed immediately after radical debridement. The average follow-up period was 17.4 months. All flaps were successful, and all wounds healed uneventfully. No further procedures were indicated. Within 1 month, C-reactive protein returned to a near-normal, stable level.


The authors described treating 15 patients with recurrent ischial pressure sores using island pedicled ALT and vastus lateralis myocutaneous flaps, transferred directly through the upper thigh to the ischial defect. A total of 16 wounds were treated: 11 with pedicled island ALT flaps and five with vastus lateralis myocutaneous flaps. The pedicle length ranged from 8.5 to 14 cm, and all transferred easily. All donor sites were closed primarily. Fifteen of the 16 flaps survived completely. One vastus lateralis myocutaneous flap underwent total necrosis.


Microsurgical free-flap surgery has progressed from simply providing wound coverage to restoring a high level of function. More recently, the concepts and practice of using compound, composite, and chimeric flaps have further enhanced the versatility of free flaps in reconstructive surgery. The authors share their experience transferring 44 LCFA system free flaps to restore structural and functional deficits caused by lower limb defects. Because of the versatility of the LCFA system, the ALT, vastus lateralis, TFL, rectus femoris, and iliac crest were incorporated to provide various tissue combinations. The following defects were treated: the patellar tendon (14), Achilles’ tendon (13), extensor hallucis tendon (2), anterior compartment with/without lateral compartment muscle (11), anterior compartment muscle and segmental tibial bone (3), and composite calcaneous (1). The success rate was 97.7%. Four flaps required reexploration and one failed. Wound infections developed in eight patients; two required amputation.


Limitations of the TFL myocutaneous flap for closing trochanteric pressure sores include its relative shortness and insufficient padding in the distal portion. To overcome these shortcomings, the authors...
reconstructed ischial and trochanteric pressure sores in eight patients using TFL combined with tangentially split vastus lateralis muscle. They included the descending branches of the lateral circumflex femoral arteries. All of the procedures were successful, and no flap necrosis occurred.


The authors studied results in seven patients having large, composite abdominal wall defects treated with bioprosthesis mesh and free or pedicled subtotal thigh flap. Eight subtotal thigh flaps (five pedicled and three free flaps with vein grafts to the femoral vessels) were reviewed. Indications for reconstruction were tumor resection, enterocutaneous fistula, and abdominal wall osteoradionecrosis. Six patients had had preoperative radiation therapy. The myofascial defect was repaired with 536.4 cm² (mean) of bioprosthesis mesh. The size of the subtotal thigh flap skin paddle was 514 cm² (mean). The mean follow-up was 27.7 months. Complications included partial flap necrosis in (one), a CSF leak (one), partial split-thickness skin graft loss (two), a focal asymptomatic myofascial bulge at the surgical site (one), and a hernia not requiring surgery (one). Bioprosthesis mesh infection, wound dehiscence, bowel obstruction, and seroma did not occur.


The authors performed an anatomic study to confirm the vascular supply of the vastus intermedius periosteal flap, a large periosteal free flap. They isolated the descending branch of the lateral femoral circumflex vessels in 11 human cadavers, preserving perforators to the vastus intermedius muscle. A cuff of vastus intermedius and approximately 75% of the circumference of the femoral periosteum were harvested from 6 cm proximal to the knee to 8 cm distal to the greater trochanter. The pedicle length and periosteal dimensions were measured. The pedicle arteries were injected with radiopaque dye and radiographed. A myoperiosteal flap was elevated with visible descending perforators in each case. The mean flap surface area was 128 cm², and the average pedicle length was 8 cm.


The authors presented a new procedure—the vastus lateralis muscle flap with grooving of the femoral shaft—for treating chronic osteomyelitis of the femoral shaft. They discussed their experience using this flap in 6 patients. All cases were successful at the 3.9-year follow-up.


The authors reported a method of free vastus lateralis muscle flap transfer for lower limb reconstruction that uses a vacuum-assisted closure (VAC) device to reduce edema and congestion. Fourteen flaps were performed in 13 patients. Complications included one flap failure, one superficial abscess, and one donor site hematoma. All patients were ambulatory at 6 months.


The vastus lateralis muscle free flap is a good choice for treating soft tissue defects of the head and neck because of its consistent anatomy, large-caliber pedicle, and low donor site morbidity. A two-team approach is possible. The authors performed a vastus lateralis muscle free flap procedure in five patients following head and neck tumor extirpation. All flaps survived. There were no recipient or donor site complications.


To better understand the applicability of the composite vastus medialis–patellar complex osseousmuscular flap for primary knee fusion, the authors studied 12 formalin-fixated cadavers. They reported data on vascular anatomy, pedicle reliability, arc of rotation, and their relation to sex, age, and height. The procedure was also performed in one patient, who had a favorable outcome after 4 months.
Posch NA, Mureau MA, Flood SJ, et al. The combined free partial vastus lateralis with an-
terolateral thigh perforator flap reconstruction of extensive composite defects. Br J Plast Surg

The authors performed free partial vastus lateralis with ALT perforator flaps in 11 patients with large
defects. Indications for adding a muscular component were exposed bone, skull base, (artificial) dura,
or osteosynthesis material; open sinuses; and lack of muscular bulk. Flaps were planned as standard
ALT flaps, with three types of dissection: (1) a true myocutaneous flap; (2) a muscle flap with a skin
island on one perforator that could be rotated up to 180 degrees; and (3) a chimera skin perforator
flap with muscle harvested on a separate branch from the source vessel or on a side branch of the skin
perforator. No total or partial flap failures occurred. In eight patients, the skin was transferred to the
facial area, and six resulted in color mismatch. Flap bulk was excessive in eight patients at 6 weeks,
and in only two patients at 6 months. Eight patients were satisfied with the functional result, and
seven were satisfied with the cosmetic result. In all of the less-satisfied patients, the flap was performed
for external facial skin reconstruction. Donor site morbidity was minimal.

Rozen WM, le Roux CM, Ashton MW, et al. The unfavorable anatomy of vastus lateralis mo-
tor nerves: a cause of donor-site morbidity after anterolateral thigh flap harvest. Plast Reconstr

The authors studied 36 human cadavers to better understand the motor nerve distribution to the
vastus lateralis and to explain the reason for donor site morbidity (although low) to the ALT flap.
No anatomic studies had previously described the relationship of these nerves to the vascular pedicle of
this flap. The relationship of the nerves to the descending branch of the LCFA was recorded. They
discovered that the nerve to the vastus lateralis branches extensively before entering the muscle, with
four to seven nerves identified per thigh. Two of the noted anatomic variations are more prone to
damage: the motor nerve passes (1) through the vascular pedicle or (2) between perforators supplying
the flap. At least 28% of cases had one or more unfavorable variations.

Sardesai MG, Yoo JH, Franklin JH, et al. Vastus lateralis muscle-only free flap: defining its role

The authors reviewed the charts of nine patients who had had muscle-only free tissue transfer for head
and neck reconstruction after tumor ablation at one center. Distal flap vascular compromise occurred in
three patients. Advantages of this flap included versatility, ease of harvest, and a two–team approach.
Disadvantages included variable anatomy and tenuous distal circulation.

Schipper J, Boedeker CC, Horch RE, et al. The free vastus lateralis muscle flap for reconstruction in

The vastus lateralis muscle was transferred as a free myocutaneous flap in six patients to reconstruct
head and neck defects after tumor removal. Five patients had a very satisfactory functional and cosmetic
outcome, without limited knee and hip movement. Immobilization was not prolonged postoperatively,
and the donor site showed no unfavorable side effects.

Shieh SJ, Jou IM. Management of intractable hip infection after resectional arthroplasty using
a vastus lateralis muscle flap and secondary total hip arthroplasty. Plast Reconstr Surg 120:202–

This article reported on the successful management of two cases of intractable hip infection using a
pedicled vastus lateralis muscle transfer as an interim procedure and then a secondary total hip arthro-
plasty to restore hip function.

Spyrounis PK, Lutz BS. Versatility of the free vastus lateralis muscle flap. J Trauma 64:1100–
1105, 2008.

The free vastus lateralis muscle flap is a versatile flap with constant anatomy, a long pedicle length,
a large vessel diameter, and minor donor site morbidity. Its dissection is easy with the patient supine.
Because of these advantages, the authors used this flap in 23 patients with various defects after trauma
and cancer therapy. They transferred a total of 24 flaps. All flaps were successful, and donor site
morbidity was minimal. Two debulking procedures were subsequently performed. Permanent partial limb dysfunction did not occur. The authors demonstrated that this flap is valuable for difficult reconstructions in a variety of areas, including the head and neck and lower limb.


The authors assessed results of 119 patients with 120 chronic infections after resection arthroplasty who were treated with a vastus lateralis muscle flap. The flap was fixed with Mitek anchors in the acetabular cavity. The mean duration of infection after resection and before the muscle flap procedure was 6.5 months. Patients had previously undergone a mean of 4.9 operations. The infected cavity was the origin of infection in all patients. The mean follow-up was 2.6 years. All patients had decreased pain and an improved quality of life. Infection did not recur.


The authors studied the vastus lateralis muscle in 15 adult formalin-fixed cadavers. The dominant pedicle was the descending branch of the LCFA. Its mean diameter was 2.1 mm. The pedicle was located 119.4 mm distal to the pubic symphysis, and it entered the muscle 155.8 and 213.7 mm from the greater trochanter and the anterior superior iliac spine, respectively. The muscle had proximal minor pedicles from the ascending and transverse branches of LCFA. These arteries had mean diameters of 1.8 and 2 mm, respectively. Distal minor branches were consistently present. The mean diameter of the distal branch was 1.8 mm; it originated 83.7 mm proximal to the intercondylar line. The motor nerve to the muscle originated from the femoral nerve and entered the muscle 194.6 mm from the anterior superior iliac spine.


The authors shared their experience with the proximal pedicled ALT flap in six patients with trochanteric defects. A total of seven island flaps were performed: four fasciocutaneous flaps in paraplegic patients with trochanteric pressure sores, and three myocutaneous flaps of the vastus lateralis muscle in patients with osteomyelitis of the trochanter and implant extrusion. The mean follow-up was 7 months. All flaps survived.


Inguinal lymphadenectomy is commonly performed for treatment of nodal metastases of primary malignancies of the lower limb, abdomen, and pelvis, often necessitating en bloc excision and producing extensive wounds with exposure of femoral vessels. The pedicled vertical rectus abdominis myocutaneous or anterolateral thigh fasciocutaneous and vastus lateralis muscle flaps are first choices for reconstruction of ipsilateral groin defects. The authors reported on their experience using contralateral pedicled anterolateral thigh–vastus lateralis flaps for immediate reconstruction of radical inguinal defects when other options were unavailable.


The pedicled anterolateral thigh–vastus lateralis muscle (ALT-VL) flap was used to reconstruct large pelvic exenteration defects in 18 patients in whom the rectus abdominis was not available for various reasons. For primary closure of perineal defects, the vastus lateralis muscle was tunneled over the inguinal ligament into the pelvis (inguinal route). For concomitant perineal-vaginal reconstruction, the ALT-VL muscle was tunneled over the medial thigh to the defect (perineal route). All patients received preoperative chemoradiation. Intraoperative pelvic brachytherapy was performed in nine patients. Complications included five small perineal wound dehiscences that healed spontaneously, one flap failure caused by pedicle tension in an obese patient with a short thigh, an enterocutaneous fistula, and an ileal conduit leak that healed spontaneously. No hernias occurred.
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>Superficial central muscle of the quadriceps extensor muscle group lying between the vastus lateralis and vastus medialis muscles. Extends from the ilium to the patella of the knee.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>Muscle: 35 × 7 cm; skin island: 9 × 30 cm with primary closure.</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>The anterior inferior iliac spine (ASIS) and the upper border of the acetabulum.</td>
</tr>
<tr>
<td><strong>Insertion</strong></td>
<td>Patella.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Extension of the knee, specifically the terminal 15 to 20 degrees.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Muscle, myocutaneous.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type II muscle.</td>
</tr>
<tr>
<td><strong>Dominant Pedicle</strong></td>
<td>Lateral circumflex femoral artery.</td>
</tr>
<tr>
<td><strong>Minor Pedicle</strong></td>
<td>Branches of the superficial femoral artery.</td>
</tr>
</tbody>
</table>
Section 12H

THIGH

Rectus Femoris Flap

CLINICAL APPLICATIONS

Regional Use
- Groin
- Perineum
- Ischium
- Inferior abdomen

Distant Use
- Chest
- Upper abdomen
- Head and neck

Specialized Use
- Abdominal wall reconstruction
- Functional muscle transfer
ANATOMY OF THE RECTUS FEMORIS FLAP

**A**
- Femoral nerve
- Femoral artery
- Superficial femoral artery
- Profunda femoris artery
- Muscular branch of femoral nerve
- Lateral circumflex femoral artery
- Ascending branch
- Transverse branch
- Descending branch
- Rectus femoris muscle
- Muscular branches of superficial femoral artery

**B**
- Anterior superior iliac spine
- Gluteus maximus muscle
- Tensor fascia lata muscle
- Femoral artery
- Profunda femoris artery
- Lateral circumflex femoral artery
- Ascending branch
- Transverse branch
- Descending branch
- Vastus lateralis muscle
- Iliotibial tract
- Sartorius muscle
- Rectus femoris muscle
- Vastus medialis muscle
- Superficial femoral artery

**Fig. 12H-1**  A, Vascular anatomy. B, Vascular anatomy with surrounding musculature.  
**Dominant pedicle:** Descending branch of lateral circumflex femoral artery  
**Minor pedicle:** Muscular branches of superficial femoral artery
ANATOMY

Landmarks  The most superficial and central of the quadriceps extensor muscle group, the rectus femoris muscle is a bipennate muscle that extends from the ilium to the patella and is surrounded by the vastus lateralis and vastus medialis muscles.

Composition  Muscle or myocutaneous. The rectus femoris muscle reliably carries its overlying skin paddle. Like other flaps of the thigh, a flap design of 9 cm or less will allow primary closure of the donor site.

Size  Muscle: 35 cm long, 7 cm wide; skin island: 9 × 30 cm with primary closure. Wider skin islands can be harvested by including perforators of the descending lateral circumflex femoral system. Donor site would require skin grafting.

Origin  Originates from the anterior and inferior iliac spine and the acetabular margin. Posteriorly, origin has two heads, which are discontinuous.

Insertion  Inserts into the upper border of the patella anterior to the continuous insertion of the vastus medialis and vastus lateralis muscles.

Function  The rectus femoris acts as an extensor of the knee, specifically powering the terminal 15 to 20 degrees of knee extension. It also is a powerful flexor of the hip. Therefore harvest of the rectus femoris muscle is not a primary flap of choice in an ambulatory patient.

Arterial Anatomy (Type II)

Dominant Pedicle  Lateral circumflex femoral artery

Regional Source  Profunda femoris artery.
 LENGTH  5 cm.
 Diameter  2 to 3 mm.
 Location  Lateral circumflex femoral artery arises from the lateral side of the profunda femoris artery. The major branch or branches are given off to the posterior surface of the muscle and its upper third. The artery then continues as the transverse branch.

Minor Pedicle  Muscular branches of the superficial femoral artery

Regional Source  Superficial femoral artery.
 LENGTH  2 to 3 cm.
 Diameter  1 mm.
 Location  Inferior third of the muscle. This vessel is not always present.

Venous Anatomy

The lateral femoral circumflex vein joins the lateral side of the femoral vein at the level of the origin of the profunda femoris artery, approximately 3 cm inferior to the inguinal ligament. Venae comitantes follow the course of the lateral circumflex femoral artery system.

Nerve Supply

Motor  The muscular branch of the femoral nerve enters the posterior surface of the muscle belly 6 to 13 cm inferior to the anterior superior iliac spine (ASIS).

Sensory  The intermediate anterior femoral cutaneous nerve (L2-L3).
VASCULAR ANATOMY OF THE RECTUS FEMORIS FLAP

Fig. 12H-2

Dominant pedicle: Descending branch of lateral circumflex femoral artery (D)
Minor pedicle: Muscular branches of superficial femoral artery (m₂)
FLAP HARVEST

Design and Markings

The skin paddle design should overlie the muscle for reliable perfusion. Unlike the tensor fascia lata flap, where the distal third of the skin is unreliable because of its largely fascial consistency, the rectus femoris muscle can reliably carry the skin paddle over its muscular component, which runs the entire length of the flap. A line drawn from the palpable anterior superior iliac spine to the central patella bisects the rectus femoris muscle and should be used in centering the flap design. A simple pinch test may help the surgeon decide how much of the width of the flap can be taken with primary closure. Conservatively, a 9 cm wide flap can be closed primarily in most patients.

A transverse line marked from the level of the pubis shows the approximate path of the lateral circumflex femoral artery. These guidepoints help in the design of the flap, which is elliptical, longitudinal, and centered over the muscle. The skin paddle can be placed anywhere within this zone. Commonly, the entire length of the skin paddle is taken and areas of skin not needed are deepithelialized. This helps to control the inevitable dog-ears at the donor site. The most proximal portion of the design would have the best blood supply.
Patient Positioning
This flap is most reliably designed and executed with the patient in the supine position. Often it is used for defects of the pubis or lower abdomen in which the patient will already be in the supine position. For use in the ischial area, the flap may be harvested with the patient in the lateral decubitus position; in this case marking in the supine position is highly recommended.

GUIDE TO FLAP DISSECTION
For a muscle-only flap, an incision along the central axis of the muscle provides the best exposure. When a skin paddle has been designed, dissection proceeds with incision of the skin paddle down to the muscular fascia. The superficial surface of the rectus femoris muscle is exposed from its origin to its insertion. Retraction of the sartorius muscle superiorly in the medial direction will expose the origin of the muscle. Inferiorly, the insertion of the muscle is exposed by freeing the vastus medialis and the vastus lateralis muscles. The tendinous insertion of the muscle is then divided, and the muscle is dissected from distal to proximal.

Fig. 12H-4  A, Location of incision for exposing the rectus femoris. B, Dissection and elevation of the muscle from distal to proximal with identification of the lateral circumflex femoral vessels.
With a large skin paddle it is useful to suture the edges of the skin distally to the fascia once the flap is elevated to prevent any shearing of the skin from the muscle during dissection. Dissection then proceeds superiorly, and the descending branch of the lateral circumflex femoral artery can be identified. Next, the surgeon encounters branches to the rectus femoris muscle at the level of the pubis. If this is a rotational flap, this would be the limit of the dissection superiorly. If this is a free flap, the dissection of the pedicle will then proceed to the profunda femoris system to maximize pedicle length and diameter of the vessels.
It is not always necessary to divide the origin of the muscle. In some cases, when extra mobility of the flap and more freedom of its placement are needed, the origin can be divided. Laterally, the muscle must be separated from the tensor fascia lata for maximum rotation.

**FLAP VARIANT**

- Functional muscle transfer

**Functional Muscle Transfer**

When the muscle is being used as a functional muscle, it is important to place reference marks on the flap in situ before the origin or insertion is divided. These marks will be used to tension the flap when inset. When harvesting the flap as a functional muscle, care is taken in dividing the origin; the femoral nerve will be identified entering the deep surface of the muscle medially, in the proximal third of the muscle. Dissection of the nerve can be carefully performed with neurolysis and separation from medial femoral nerve branches and the motor branches to the vastus muscles.

Because of the arrangement of its muscular fibers, the rectus femoris muscle can only contract 4 to 5 cm. This limited excursion makes it less useful than other more expendable muscles for functional muscle transfer. Because there is some morbidity in harvesting the flap, one must carefully consider other options for solving the reconstructive problem at hand.
**ARC OF ROTATION**

The positioning of the proximal vasculature is favorable for arc of rotation of the flap to the lower half of the abdomen and the groin area. Posteriorly, the flap will easily reach to the area of the ischium. Dissection of the pedicle more proximally, because of its short size, does not significantly increase the arc of rotation. Release of the tendon origin may assist in flap positioning and some flap advancement medially.

![Anterior arc to abdomen](image1)

![Posterior arc to ischium](image2)

*Fig. 12H-6*
FLAP TRANSFER

Muscle-Only Flap
Once elevated, muscle can be transferred to its abdominal or ischial recipient site through a subcutaneous tunnel. The surgeon must ensure that the tunnel is wide enough that there is no compression on the proximal pedicle and that no kinking or torsion has occurred after transfer.

Myocutaneous Flap
A myocutaneous flap can be transferred either through a subcutaneous tunnel or by direct extension of the donor site with the defect. For most groin defects or nearby lower abdominal defects, extension and connection of the recipient and donor sites allow better inset of the flap and less likelihood of compression of the pedicle or kinking or torsion on the flap pedicle.

FLAP INSET
The rotated flap should be inset without tension. The advantage of the rectus femoris flap is the generous amount of fascia with the muscle, and this fascia should be used for distributing tension along the closure, especially for an abdominal wall fascial defect.

Free Flap
The abundant fascia present in the muscle is used to support the free tissue transfer in place before microvascular anastomosis. The anastomosis must be tension free.

DONOR SITE CLOSURE
All Flap Variants
When possible, direct donor site closure is recommended. A skin island of 9 cm or less should permit closure, and widths of up to 15 cm have been closed primarily in select patients. Because of the potential functional morbidity of losing the rectus femoris muscle, it is advised that distally, the vastus lateralis and vastus medialis muscles be united in the midline with permanent suture. Reapproximation of the vastus lateralis and vastus medialis muscles for 10 to 15 cm distally will help compensate for functional loss. Skin grafting can be unsightly but can functionally close the donor site. Skin grafts over the patellar mechanism should be avoided when possible.
CLINICAL APPLICATIONS
This 47-year-old woman was referred from the vascular service for an exposed Gore-Tex graft after vascular bypass surgery. The wound was thought to be clean, and coverage rather than removal and rerouting of a new graft was planned. Reconstructive options for this clinical problem include the use of muscle for coverage. Skin closure is usually not an issue. Options for local muscle flap include the sartorius, gracilis, rectus femoris, and rectus abdominis muscles. The tensor fascia lata supplies fascia but not muscle over the graft. The flap choice is dictated by the defect, the reconstructive need, and the remaining blood supply after bypass. In this case, a rectus femoris flap was chosen.

Fig. 12H-7  A, The groin wound was debrided and irrigated and the rectus femoris was isolated distally through a more limited approach to minimize wound-healing issues. B, The muscle was released from its attachments distally and was dissected up to the lateral circumflex femoral pedicle. The muscle was then rotated through 180 degrees of rotation, keeping the muscle belly down on the exposed graft. Note the excess available flap to ensure a tension-free inset. C, The flap was inset, using the accompanying fascia to secure the flap tension free, sealing off the graft. Primary skin closure was easily obtained. (Case supplied by MRZ.)
This 73-year-old woman had a liposarcoma of the abdominal wall. Resection included the full-thickness abdominal wall, leaving both a large skin defect and a fascial defect. Options included synthetic mesh closure and coverage with abdominal skin mobilization, or a skin-bearing flap. One could also consider reconstruction of fascia and skin with a rotational flap such as the tensor fascia lata, rectus femoris, or contralateral rectus abdominis. In this case, a rectus femoris myocutaneous flap was planned for the complete reconstruction.

Fig. 12H-8  
A, The operative defect is shown, with missing skin, muscle, and fascia. The planned flap was marked. Proximal skin markings were adjusted medially to assist inset of the flap laterally. B, Dissection of the flap with identification of the lateral circumflex femoral pedicle, which was the limit of dissection on the deep surface. Note that the extra fascial extension was taken to assist in fascial closure. C, The flap was rotated and prepared for inset. Note the clamps that show the extent of the fascia available for repair of the defect. Release of the origin of the muscle proximally was performed to assist in positioning of the flap. D, Final inset of the flap. The edges of the vastus lateralis and vastus medialis were approximated for 15 cm above the patella with nonabsorbable suture. Primary skin closure was performed, as planned preoperatively. (Case supplied by MRZ.)
This 45-year-old woman had a history of cervical cancer that had been treated with resection and irradiation. She remained disease free but had a chronic wound in the pubic area from the radiation. Attempts at secondary closure and skin grafting had failed, and the patient was referred for reconstruction. Choices for local flaps in this case include tensor fascia lata, rectus femoris, and rectus abdominis flaps. In this case, a rectus femoris flap was chosen to allow fascial reinforcement, muscle for added vascularity to the irradiated wound, and skin for closure.

Fig. 12H-9  A, The patient’s chronic wound is shown, with some granulations but no reepithelialization. Some of the anterior fascia was missing, with exposed rectus abdominis muscle in the wound. B, Planned rectus femoris myocutaneous flap. C, Flap inset. The donor and recipient sites were connected, allowing transposition without the need for tunnels and possible flap compression under tight, irradiated skin. Resection of the irradiated skin was performed to allow flap inset. Primary donor site closure was obtained. D, The final result after flap dehiscence requiring debridement and reinset. (Case supplied by MRZ.)
This 62-year-old man had a bladder cancer invading the abdominal wall, requiring full-thickness abdominal wall resection, a cystectomy, and creation of a urinary conduit. The rectus femoris is an excellent choice for fascial replacement when there is a large skin requirement.

**Fig. 12H-10**  
A, A primary fascial closure was not obtainable in this area of the pubis.  
B, Elevation of the rectus femoris flap with identification of the vascular pedicle.  
C, The flap was rotated, with tension-free reach and adequate tissue for reconstruction. Primary fascial closure was obtained using the fascia of the rectus femoris.  
D, The flap inset. The donor and recipient sites were united to allow better flap inset and no compression of the vascular pedicle.  
E, The patient is shown at his 2-week follow-up. Healing was uneventful. (Case supplied by MRZ.)
This 55-year-old man had a large groin sarcoma requiring full-thickness resection of the abdominal wall, a penectomy, and resection of the right testis. The fascial defect was repaired with mesh, and the overlying soft tissue was repaired with a rectus femoris flap.

**Fig. 12H-11**  
A, The defect and the proposed rectus femoris flap are shown. The large soft tissue defect required a large flap that necessitated skin grafting of the donor site. B, The flap was elevated, the fascial defect was closed with mesh, and the femoral vessels were covered with the sartorius muscle. C, Flap inset and donor site skin grafted. D, The patient is shown at his 3-month follow-up. Healing was uneventful. (Case supplied by MRZ.)
This 45-year-old man had been treated for lung cancer 8 years previously with chemotherapy and irradiation. The patient presented with a chest wound; a biopsy revealed a spindle cell malignancy. The patient had documented metastatic disease, and a heroic chest wall resection was proposed by thoracic surgery for pain control, wound management, and possible further adjuvant therapy.

Fig. 12H-12  A, A chest wound from a spindle cell malignancy with necrosis and obvious subcutaneous metastases and skin involvement. The proposed area of resection was marked. B, Operative defect with bilateral intrathoracic exposure. The local pectoralis major and minor muscles were rotated to cover the exposed ribs and clavicle. C, Design of the rectus femoris flap to be transferred as a free tissue transfer. The size of the flap required skin grafting of the donor site. D, The flap inset. The lateral circumflex femoral artery was anastomosed end-to-end to the facial artery and the lateral circumflex vein was anastomosed to an internal jugular vein branch. Purulence was present, so no mesh was placed, and complete fascial closure was obtained with the fascia carried with the flap. Because of the purulence, the wound was left partially open superiorly and was packed. Although the flap healed well, the patient’s clinical course deteriorated. (Case supplied by MRZ.)
This 69-year-old man had a recurrent squamous cell carcinoma of the scalp that required wide excision, orbital exenteration, parotidectomy, and lymph node dissection. His complex wound required muscle for exposed dura at its base, and a large amount of vascularized tissue for skin closure. A large flap of the anterior thigh was used, incorporating the rectus femoris muscle with its primary blood supply, supplemented with surrounding perforators from the descending branch of the lateral circumflex femoral system (anterior lateral thigh and anteromedial thigh perforators).

Fig. 12H-13 A, The operative defect is shown, with an exposed dural and large skin defect. A cheek flap was elevated for parotidectomy and lymph node dissection, providing exposure to the neck vessels as recipient vessels for free tissue transfer. B, Lateral view of the flap elevation showing the perforators of the anterior lateral thigh to be included with the flap. C, Medial view of the flap showing the anteromedial thigh perforators, also included with the flap. The rectus femoris, anterior lateral thigh, and anteromedial thigh vessels share a common lateral circumflex femoral source and can be carried together with one microvascular pedicle connection. D, View of the undersurface of the flap showing the rectus femoris muscle divided distally and the vascular pedicle isolated up to the source profunda femoris system. E, Flap inset with rectus femoris muscle covering the dural defect and adequate skin for closure. Microvascular anastomosis was performed end-to-end to the superficial temporal system. The donor site was skin grafted. The flap and the donor site healed well postoperatively. (Case supplied by MRZ.)
A 57-year-old man who had undergone low anterior resection for colon cancer developed a 12 by 15 cm recurrence in the right lower quadrant of the abdominal wall at a previous diverting colostomy site. The mass involved the small and large bowels and the full thickness of the abdominal wall.

**Fig. 12H-14**  
**A**, A right thigh–based flap was planned for cutaneous coverage of the anticipated composite resection defect. The vascular anatomy of the lateral circumflex femoral system was marked on the patient’s right leg.  
**B**, The composite resection defect included skin, subcutaneous tissue, and a 15 by 20 cm segment of abdominal wall myofascia.  
**C**, After bowel anastomoses, the myofascial defect was bridged with an inlay of acellular dermal matrix.  
**D**, A rectus femoris myocutaneous flap was elevated from the right leg to repair the cutaneous defect in the right lower quadrant.
The proximal portion of the flap was deepithelialized, and the flap was subsequently tunneled subcutaneously under the groin skin. A 15 cm distal tenorrhaphy of the vastus lateralis to medialis tendons was performed. A subsartorial transposition was performed to maximize the superomedial reach of the flap. The vascular pedicle was located medial to the sartorius muscle after the flap was transposed under the sartorius muscle. This maneuver added approximately 6 cm to the flap’s reach, allowing a tension-free inset. Intraoperative appearance of the primarily closed donor site and flap inset. Appearance of the donor and recipient sites 3 weeks after reconstruction. (Case courtesy Charles E. Butler, MD.)
This 27-year-old woman had a history of advanced cervical cancer. She had previously undergone a radical hysterectomy and pelvic lymph node dissection followed by postoperative chemotherapy and radiation therapy. She developed a 17 by 20 cm recurrence in the pelvis involving the full thickness of the abdominal wall.

Fig. 12H-15  
A, Preoperative appearance showing cancer recurrence.  
B, Computed tomography scan through the lower abdomen demonstrating tumor recurrence involving the full thickness of the abdominal wall as well as the small bowel, large bowel, and bladder.  
C, Preoperative markings for a planned rectus femoris flap to repair the planned composite resection defect. The vascular anatomy of the lateral circumflex femoral vessels and the borders of the rectus femoris muscle are marked on the right leg.  
D, The 20 by 20 cm composite resection defect. The small and large bowels were resected and reanastomosed, and a partial cystectomy was performed.
The myofascial defect (which was in previously irradiated tissue) was bridged with an inlay of acellular dermal matrix. 

A large rectus femoris myocutaneous island flap was elevated and transposed superomedially under the sartorius muscle to increase the flap's reach. This allowed the entire defect to be repaired with a single flap without tension on the flap inset. 

Closer view of the subsartorial transposition. The lateral circumflex femoral pedicle was transposed superomedial to the sartorius muscle, markedly reducing the course that the pedicle traveled and thus increasing the flap's reach. The proximal myotendinous origin of the rectus femoris muscle was tacked to the vastus lateralis myofascia to prevent inadvertent traction on the vascular pedicle. 

The skin grafted donor site and recipient site 3 months after the reconstruction. (Case courtesy Charles E. Butler, MD.)
Pearls and Pitfalls

- Care must be taken when dissecting the vascular pedicle, because the motor branches of the femoral nerve to the adjacent vastus lateralis and tensor fascia lata are nearby and must be preserved.
- The rectus femoris flap provides more fascia than its neighboring tensor fascia lata flap; it also provides abundant vascular muscle when reconstructive needs require this.
- Use of the anterior lateral thigh flap has largely supplanted the use of the rectus femoris flap for skin cover. The anterior lateral thigh flap is based on the same lateral circumflex system but avoids sacrifice of a functional muscle.
- A megaflap comprising the entire anterior thigh can be elevated with the rectus femoris muscle incorporating both anterior lateral thigh perforators and anteromedial thigh perforators, in addition to the perforating vessels of the rectus femoris muscle. This allows perfusion to a greater area of skin cover than the tensor fascia lata, anterior lateral thigh, or rectus femoris flap alone.
- To prevent loss of active knee extension in the terminal 15 degrees, the vastus lateralis and vastus medialis should be approximated in the midline for about 15 cm above the knee with permanent suture.
- Although some patients will have a minor pedicle from the superficial femoral system, it is not advisable to create a flap based on this system, because it will not reliably carry the muscle after the division of the major pedicle.

EXPERT COMMENTARY
Charles E. Butler

Indications
A frequent indication for the rectus femoris flap is reconstruction of defects of the lower abdominal wall. Other indications include reconstruction of defects in the groin, perineum, pubis, and proximal thighs. A muscle-only or myocutaneous rectus femoris flap with a deepithelialized skin paddle can efficiently obliterate dead space. Moderately large cutaneous defects can be closed with a myocutaneous flap or muscle flap with a skin graft. The arc of rotation of this flap allows it to reach the lateral hip area, lower abdominal wall, groin, perineum, and proximal thighs. A free rectus femoris flap can also be used in functional muscle reconstruction, particularly for flexors in the hand.

Advantages and Limitations
Major advantages of the rectus femoris flap are the large volume of muscle bulk and the large skin island surface area that can be harvested while still enabling primary closure of the donor site, with negligible functional morbidity. Furthermore, this flap is relatively straightforward and can be rapidly elevated and inset. It can be harvested as a pedicled or free flap; the latter has large-caliber donor vessels, particularly if the pedicle is dissected completely to the origin of the lateral circumflex femoral vessels. If a rectus femoris flap is used as a muscle-only flap without transection of the descending branch of the lateral circumflex femoral vessels, an ipsilateral anterolateral thigh and/or vastus lateralis flap may still be an option for a secondary or salvage reconstruction.
Disadvantages of the rectus femoris flap include the relatively short vascular pedicles, particularly with the free flap. The rectus femoris flap is less versatile than the anterolateral thigh flap under several circumstances. In general, the rectus femoris flap is thicker than the anterolateral thigh flap and requires the inclusion of muscle. In contrast, the anterolateral thigh (ALT) flap can be performed as a perforator flap or may include the vastus lateralis muscle, either attached to the flap or as a muscle island flap–based separate perforator or perforators. Because there are several distinct perforators to the ALT flap’s skin island, the flap can be split into two or three skin islands based on each individual perforator and be used to repair multifocal defects without the need for another flap. If needed, thigh fascia can be included with the ALT flap and will generally be of better quality than fascia of the rectus femoris flap. In addition, the ALT flap is generally more pliable and can be contoured, tubed, and sculpted more easily.

**Anatomic Considerations**

There are a considerable number of common variations of the lateral circumflex femoral vessels, their branches, and the rectus femoris pedicle itself. The take-off of the rectus femoris pedicle may be from the main trunk of the lateral circumflex femoral vessels or from one of their three major branches. In some cases, there are two separate perforators entering the rectus femoris muscle, often from different branches of the lateral circumflex femoral system. Surgeons should be aware of these potential anatomic variations and carefully assess the vascular anatomy during pedicle dissection.

Dissection to the origin of the lateral circumflex femoral vessels is helpful if a longer pedicle or larger-diameter recipient vessels are required. This may require transection of the ascending, descending, and transverse branches of the lateral circumflex femoral system, particularly when a free flap is used.

While dissecting the flap from its donor site, the surgeon must avoid inadvertent injury to the vastus lateralis and vastus medialis tendons to the patella. Generally, a V-shaped segment of rectus femoris tendon can be sharply excised from the center of the tendinous confluence without weakening the adjacent vastus medialis and lateralis tendons.

**Personal Experience and Insights**

Overall, this is a very reliable and relatively straightforward flap, particularly for locoregional reconstruction. It can be used to reconstruct a wide variety of defects with minimal donor site morbidity.

Anatomic markings, as described in the chapter, are helpful for identification of the muscular anatomy. However, when the thigh does not have excessively thick subcutaneous tissue, I find the most effective and accurate method of identifying and marking the muscle anatomy of the rectus femoris flap is palpation of the thigh with the patient awake. While the patient is supine, his or her hip is flexed to 30 degrees and the knee is placed at 45 degrees flexion. The patient is then asked to extend the knee against an assistant’s hands; the contractions of the rectus femoris muscle can be palpated through the skin, and the muscle borders are marked on the skin. Identification of the medial and lateral borders of the rectus femoris muscle in relation to the skin helps define the appropriate location for skin island design.

To ensure reliable vascularity, the skin paddle should be located directly over the rectus femoris muscle. During the flap dissection it is helpful to identify the location of the rectus femoris muscle distally before committing to the exact location of the skin island, particularly if the subcutaneous thigh tissue is thick and/or the planned skin island...
is small. I generally start the dissection distally to identify the myotendinous area of the rectus femoris muscle situated between the vastus lateralis and medialis muscles. The rectus femoris muscle is then distracted distally so that the muscle location can be visualized and palpated through the thigh skin. The skin island can then be defined and elevated medial and lateral to the muscle as the dissection proceeds cranially. This ensures that the skin island is located directly over the muscle and maximizes the skin island’s vascularity.

Skin paddles larger than described in the chapter can be harvested; however, this increases the likelihood that a skin graft will be required to repair the donor site. It is helpful to avoid placing a skin graft over the distal aspect of the thigh owing to the presence of the vastus lateralis and vastus medialis tendons in this area. Surgeons should attempt to close this area primarily if at all possible.

An extended ALT or subtotal thigh flap is a better option for extremely large defects that the rectus femoris flap cannot reliably accommodate.

**Recommendations**

**Planning**

When the characteristics of the resection defect are not exactly known, reconstructive surgeons should be prepared to modify their plans accordingly. The entire thigh and lower leg should be prepared and available for use in the event that an alternative flap, such as an anterolateral thigh, subtotal thigh, tensor fascia lata, or vastus lateralis flap, will be needed. Furthermore, this allows access to the saphenous vein for vein grafts or a vein loop in the event a free tissue transfer is required to reach more distally than initially anticipated. The contralateral thigh should also be prepared for a skin graft in case a large skin paddle is required.

**Technique**

A subsartorial transposition is an extremely valuable technique to increase the arc of rotation of the rectus femoris flap when a defect is located superior and/or medial to the donor site. The vascular pedicle of the rectus femoris flap enters the muscle lateral to the sartorius muscle, whereas the origin of the lateral circumflex femoral vessels is medial, and generally superior to, the pedicle entry site. Transposing the flap superomedially, under the sartorius muscle, maximizes the flap’s reach and ensures that the pedicle does not wrap around the lateral border of the sartorius muscle. This maneuver is particularly helpful for lower abdominal wall reconstructions and for defects in the perineal area that cross the midline.

The importance of a vastus medialis to lateralis tenorrhaphy, as mentioned in the chapter, cannot be overestimated. To minimize potential loss of central knee extension function from harvest of the rectus femoris muscle, tenorrhaphy of the vastus medialis to lateralis tendons is performed to transpose the force vectors of the two muscles more centrally and anteriorly to augment knee extension force. Perhaps as important, this maneuver can help advance the skin defect edges, taking tension off them and reducing the risk of wound breakdown in the distal thigh. Buried, interrupted 1 polypropylene sutures are often used for the tenorrhaphy, and extending the tenorrhaphy for 15 cm is common. The tenorrhaphy usually results in centralization of the vastus medialis and lateralis muscles just cranial to the muscle–tendon junction.
**Postoperative Care**
I find it helpful to place the patient in a knee immobilizer postoperatively. This reduces the risk of donor site wound dehiscence and disruption of the tenorrhaphy. A knee immobilizer is also extremely helpful when a skin graft has been used, to reduce the shear and/or traction that is caused by knee flexion. Patients are allowed to ambulate with the knee immobilizer in place. Generally, patients discontinue the knee immobilizer after 1 week if no skin graft was used and after 2 weeks if skin grafting was done.

**Complications: Avoidance and Treatment**
Several complications can commonly occur with this flap, many of which can be prevented. Inadvertent traction on the vascular pedicle is a devastating complication that can result in complete or partial flap failure. Extreme care should be used when insetting this flap to avoid potential pedicle traction; in particular, the effect of mobility at the hip joint on the pedicle should be anticipated. To prevent traction on the pedicle, it is helpful to suture the transected proximal rectus femoris tendon to thigh muscle and/or fascia 180 degrees opposite from the direction of the flap inset. To confirm that this maneuver has eliminated the possibility of pedicle traction, axial tension should be placed on the flap and the pedicle examined.

**Take-Away Messages**
The rectus femoris flap is quite reliable, with excellent muscle volume and good skin island surface area. The flap is quite versatile, because it can be used as a muscle-only or myocutaneous flap. Flap harvest causes relatively minimal functional morbidity, and the donor site can be concealed easily with clothing. The ALT flap is often preferred over the rectus femoris flap when a long vascular pedicle is required and/or a very thin perforator-based flap (without muscle) is desired. The actual rectus femoris pedicle length is relatively short; however, there are techniques to extend both the pedicle length and overall flap reach.

**Bibliography With Key Annotations**

Pressure ulcers that communicate with the hip joint are very difficult to treat. Often the hip joint is infected with osteomyelitis of the proximal femur, resulting in bouts of sepsis and flap failure. These patients require proximal femoral resection and wide debridement to eradicate the infection, which in turn results in large, deep cavities. Reconstruction requires either a muscle flap or even a total thigh flap if the defect is very large and the pelvis is involved. In a series of six ischial or ischirotrochanteric pressure sores communicating with the hip joint following multiple serial debridements, the vastus lateralis, vastus intermedius, and rectus femoris muscles were raised as a single myocutaneous flap (“three-muscle flap”), based on the descending branch of the lateral femoral circumflex artery, and transposed into the defect. All patients were paraplegics and had signs of sepsis during admission. Two patients had prior failed reconstructions within 3 months of admission, and the others had not been operated on previously. The external skin defect of their ulcers ranged from 7 by 5 cm to 30 by 12 cm. After 12 months’ follow-up, there was no recurrence of pressure sores or sepsis. The three-
muscle flap offers the advantage of providing large bulk to fill deep cavities, while preserving the rest of
the thigh. The flap elevation is fast and safe and the vascular pedicle is reliable. This technique is not
for simple pressure sores, but should be reserved for large pressure sores complicated with large cavities
created after resection of the proximal femur.

Alkon JD, Smith A, Losee JE, et al. Management of complex groin wounds: preferred use of

This study reviewed the authors’ experience with the rectus femoris muscle flap for complex groin
wound reconstruction. The rectus femoris has become their routine method of groin wound reconstruc-
tion. The rectus femoris is harvested through a midanterior incision extending over the distal two
thirds of the thigh. The muscle is elevated on its pedicle and transposed into the groin wound defect
either directly or through an intervening skin bridge. Hospital and outpatient records were reviewed
for all patients undergoing groin wound reconstruction with this technique from 1999 through 2003.
Thirty-seven rectus femoris muscle flaps were performed in 33 patients. The mean patient age was
65.3 years (range 25 to 88 years). Thirty groin wounds occurred after infrainguinal revascularization,
23 of which contained prosthetic material. In 5 of these wounds the prosthetic material was removed
at reconstruction. The remaining 7 groin wounds occurred after femoral vessel cannulation for either
cardiac or transplant surgery. There were no intraoperative mortalities, no anastomotic hemorrhages, and
no flap losses. Thirty-five of the 37 treated wounds healed, 26 primarily and 9 after delayed healing
and contracture. Reoperation was performed in 1 patient for flap readvancement and in 3 patients for
prosthetic graft removal after initial flap reconstruction. Two patients died during their hospitalization
with persistent open groin wounds after flap reconstruction. All muscle flap donor incisions healed;
only 2 had minimal delayed healing. There were no donor site wound infections, and no donor sites
required reoperation. Thirty-three groin wounds demonstrated culture-positive microbial infection, 15
of which were polymicrobial. The 30-day mortality rate was 13.2%; the 6-month mortality rate
increased to 27.2%, with multisystem organ failure as the most common cause of death. The rectus
femoris muscle flap is an effective and reliable means of complex groin wound reconstruction. The
muscle flap is dependable, and the donor site is not problematic, even in the presence of peripheral
vascular disease. The authors stated that the rectus femoris muscle flap is the flap of choice for groin
wound reconstruction.

Cardosi RJ, Hoffman MS, Greenwald D. Rectus femoris myocutaneous flap for vulvoperineal

Many reconstructive procedures for large vulvoperineal defects have been described. The authors re-
ported the use of the rectus femoris myocutaneous flap, which had not previously been described for this
purpose. A 52-year-old woman had a local recurrence of a Bartholin’s gland carcinoma after anterior
exenteration and pubectomy. A palliative resection was performed that resulted in a large vulvoperi-
nal defect with transpelvic herniation of the peritoneal contents. This was immediately reconstructed
with a rectus femoris myocutaneous flap. Her postoperative course and healing were uneventful. This
technique is an alternative method for vulvar reconstruction. It is especially useful for large defects when
a gracilis or rectus abdominis flap is not available.


Groin infections adjacent to vascular bypass grafts continue to be a source of morbidity. The authors
retrospectively reviewed nine consecutive patients with early localized groin infections treated with
sartorius or rectus femoris muscle flaps between 1998 and 2002. All wounds were initially opened
and drained. Wounds with necrotic tissue were treated with serial surgical debridements, with a
vacuum-assisted closure device, or with wet-to-dry dressing changes. Two bypass grafts were excised
and replaced in the presence of marked exposure or pseudoaneurysm. Small wounds were closed with
a turnover sartorius flap and larger wounds were closed with either a muscle or myocutaneous rectus

The authors evaluated donor site morbidity in four patients after reconstruction with free neurovascular rectus femoris muscle through a series of strength tests in which the leg with rectus femoris muscle harvested was compared with the contralateral leg with an intact rectus femoris muscle. The tests were conducted with three testing devices: (1) the Con-Trex Leg-Press, in which the force and power of right and left leg extensions at 0.2 and 0.4 m/s in a knee angle from 50 to 90 degrees were tested separately; (2) the isometric power tester, which enabled unilateral evaluation of isometric leg extension at three knee angles: 50, 70, and 90 degrees; and (3) the SP-Force Platforms, in which the patients performed a countermovement jump where the amplitude of the ground reaction force, the parameters maximum force, and the jump height were calculated to compare the right and left leg during a single dynamic movement. Results showed that the patients (with one exception) demonstrated a balanced relationship between the donor leg and the intact contralateral leg. The patient who initially demonstrated a large strength deficit was retested 3 months later, after an extensive rehabilitation and training program, and showed an impressive increase in strength. The authors concluded that there is no significant limitation in the strength of the donor leg after removal of the rectus femoris muscle and consequently no significant functional donor site morbidity. They stated that for the realization of such results, the intraoperative linking of the vastus lateralis muscle with the vastus medialis muscle, especially in their lower third, are essential, as is an extensive postoperative rehabilitation and training program.


Although the anterolateral thigh flap is used by many instead of the radial forearm free flap for reconstruction of defects after hemiglossectomy, the shape of the patient’s body invariably dictates the volume of tissue harvested. Here a chimeric vastus lateralis free flap was described as an alternative. For the surgeon familiar with the anatomical territory of the anterolateral thigh, this may be a useful option in certain clinical circumstances.


Reconstruction of large abdominal wall defects with conventional reconstruction including the component separation technique is difficult because of strong transverse tension and loss or weakness of the rectus abdominis muscle. To overcome this problem, dynamic reconstruction of the abdominal wall using a
free innervated rectus femoris myocutaneous flap was performed for large defects with separation of the bilateral rectus abdominis muscles. The intact motor nerve of the rectus femoris muscle was transferred without transection, and only the pedicle vessels were Anastomosed to the omental vessels. Evaluated 4½ years after surgery, the rectus femoris muscle had voluntary strong muscle contraction, and there was no abdominal protrusion, herniation, or donor morbidity. This method with dynamic function can replace conventional techniques for large abdominal defects without rectus muscle function.


Microsurgical free-flap surgery has progressed from simply providing wound coverage to restoring a high level of function. The concepts and practice of using compound, composite, and chimeric flaps have further enhanced the versatility of free flaps in reconstructive surgery. A lateral circumflex femoral arterial (LCFA) system can provide a potential single composite free-tissue transfer for restoration of functional and structural integrity. Between 1997 and 2003, we used 44 free flaps to restore functional and structural defects in the lower limbs. The versatility of the LCFA system allowed utilization of the anterolateral thigh, vastus lateralis, tensor fascia lata, rectus femoris, and iliac crest. Combinations of tissues from this system were employed to restore defects in the patellar tendon (14), Achilles tendon (13), extensor hallucis tendon (2), anterior compartment with or without lateral compartment muscle (11), anterior compartment muscle and segmental tibial bone (3), and composite calcaneus (1). The free-flap success rate was 97.7%. Four reexplorations were performed, with 1 subsequent failure. Eight patients (18.2%) developed wound infections, of which 2 required secondary amputations, resulting in a limb salvage rate of 95.4%. The LCFA system provides a predictable and versatile surplus of tissue necessary to restore functional and structural integrity of the posttraumatic lower extremity in a single stage.


A 72-year-old man with a third recurrence of a low-grade liposarcoma of the right lower leg sought limb-salvage surgery. The tumor was removed en bloc with all the superficial posterior compartment of the leg. Appropriate foot flexion was restored by means of a free functional rectus femoris myocutaneous flap harvested from the ipsilateral thigh. The patient was kept in a splint for 6 weeks postoperatively. Three months after the operation, clinical and electromyographic signs of reinnervation were observed. The patient was able to walk, run, and climb stairs, and no donor site morbidity was observed. Thigh extension was rated M4, comparable to the contralateral thigh. Foot flexion, without any postoperative exercise, was rated M3, with a 30-degree excursion. This was the first report of reconstruction of the posterior compartment of the leg with a free functional rectus femoris flap, and the authors stated that this muscle could be the ideal option for such reconstruction.


Advantages of the pedicled rectus femoris myofascial flap for groin wound coverage include a sufficient arc of rotation to reach the groin and inguinal region, a dependable vascular pedicle, and low donor site morbidity. One hundred six rectus femoris flaps were performed for groin wound reconstruction over a 10-year period. From this cohort, consent was obtained from 20 patients for testing of thigh function. Testing included a subjective patient questionnaire assessing postoperative thigh strength and objective muscle strength testing using isometric dynamometer analysis. An age- and sex-matched control group of 20 subjects with no operative history or known discrepancy of thigh strength underwent identical
testing. Subjects were tested an average of 33 months postoperatively. Dynamometer studies demonstrated a mean nonoperative and operative thigh peak torque of 135 ft-lb and 104 ft-lb, respectively, or a 21% difference in isometric knee extensor strength favoring the dominant leg. Similarly, the control group exhibited a 17% strength difference between both thighs. Operative subjects exhibited a lower peak torque generated by the operative leg relative to the nonoperative leg. However, a similar difference was observed in the matched control cohort. Thus there is little isolated deficit in quadriceps strength as a result of rectus femoris harvest.


A 22-year-old patient sustained a complex injury of the left brachial plexus. Primary brachial plexus reconstruction did not lead to any functional recovery. Twenty-six months later, the patient demonstrated an upper brachial plexus palsy that precluded the possibility of performing a latissimus dorsi muscle transfer. To reestablish elbow flexion, a free myocutaneous neurovascular rectus femoris flap, harvested from the left thigh, was neurotized to the accessory nerve using a sural nerve graft. Ten months after the free functional rectus femoris transfer, early electromyographic results were detected, and 7 months later, strong reinnervation signs occurred. Because of dissatisfaction with the aesthetic results, including an indentation in the left shoulder and pectoral region, two silicone implants were inserted 41 months postoperatively. A few hours after the operation, the patient experienced palsy of the transplanted muscle. The silicone implants were removed immediately. Initial recovery of muscle function was detected by electromyography 4 months later, and complete reinnervation was observed 8 years postoperatively. Elbow flexion was rated M4, and the patient had no functional donor site morbidity. The authors concluded that free rectus femoris muscle transfer offers excellent results when effort is put into postoperative rehabilitation with extensive training programs.


Two patients underwent restoration of knee extension with a free neurovascular rectus femoris flap. The female patient was 10 years old and the male patient 19 years old. Both had sustained a complex trauma of the thigh, with fracture of the femur and posttraumatic loss of quadriceps femoris muscles. Follow-up of the patients was 51 and 27 months, respectively. After 8 months, reinnervation was detected by electromyography in both patients, and contraction became visible 2 months later. The girl obtained a good and the young man a very good functional result. Both patients were able to walk unaided.


In severely injured lower extremities with loss of the anterior compartment, the free functional rectus femoris myocutaneous flap was used to restore extension of the foot and in soft tissue reconstruction. From June 2000 to July 2002, three patients were treated with this technique. Mean follow-up was 27 months. Electromyography and the Stanmore system (recording pain, need for orthosis, ability to wear normal shoes, activity level, muscle power, active extension of the foot, and foot posture) were used to assess the results of the functional rectus femoris transfer. One patient had an excellent result, one had a good result, and one patient had a poor result, as assessed by the Stanmore system. Free functional rectus femoris transfer can produce excellent results in treating footdrop and soft tissue defects from lower leg compartment syndrome and loss of all muscles of the anterior compartment.

The authors investigated the intramuscular neurovascular anatomy and intramuscular tendon distribution of the rectus femoris muscle to reassess the reliability of technique of harvesting a longitudinally split segmental muscle flap. They presented their clinical experience on the usefulness of the longitudinally split segmental rectus femoris muscle flap as a method for reconstruction of the paralyzed face in 25 patients. Twenty fresh cadavers were systemically injected with lead oxide, gelatin, and water. Based on the anatomy of intramuscular neurovascular structure in the rectus femoris muscle, 25 consecutive patients with established facial paralysis were treated by using a two-stage method combining neurovascular free muscle transfer with cross-face nerve grafting. Follow-up was from 15 to 24 months. All of the 25 patients showed significant improvement in the appearance of the oral commissure and in oral competence. Satisfactory results of facial reanimation were obtained in 23 patients. Among these cases, near-natural facial expression was achieved. Recovery continued up to 2 years postoperatively. Two patients had poor movement of transferred muscle 2 years postoperatively. No complications occurred in the donor site.
Chapter 13

Leg

The leg presents unique reconstructive challenges, given its dependency and tendency to develop peripheral vascular disease and venous stasis disease. The relative paucity of well-vascularized muscle in the distal third of the leg has vexed surgeons for ages. The leg can provide several useful and extremely reliable flaps for proximal and middle third defects. The distally based sural artery flap has become popular in the reconstruction of lower third and foot defects where local tissue options have traditionally been deficient. The leg also houses the most popular vascularized osteocutaneous flap in the body—the fibula flap—universally used wherever vascularized bone is required as part of a reconstruction.

Fibula Flap
Soleus Flap
Sural Artery Flap
Gastrocnemius Flap
Anterior Tibial Flap
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>The fibula flap occupies the lateral aspect of the leg. The bone is a straight, strong, tubular bone that plays a minor role in weight-bearing and stability of the lower extremity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Bone: 25 cm; skin: 25 cm long, 3 cm wide, with primary closure.</td>
</tr>
<tr>
<td>Composition</td>
<td>Bone, osteocutaneous, osteomyocutaneous.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Peroneal artery.</td>
</tr>
<tr>
<td>Minor Pedicles</td>
<td>Lateral inferior genicular artery; anterior tibial artery.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td>Superficial peroneal nerve.</td>
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Section 13A

LEG
Fibula Flap

CLINICAL APPLICATIONS

Regional Use
- Ipsilateral tibia

Distant Use
- Head and neck
- Upper extremity
- Lower extremity
- Pelvis

Specialized Use
- Mandible reconstruction
- Avascular necrosis of femoral head
ANATOMY OF THE FIBULA FLAP

Dominant pedicle: Peroneal artery
Minor pedicles: Lateral inferior genicular artery; anterior tibial artery
ANATOMY

Landmarks  The fibula flap occupies the lateral aspect of the lower leg. Fibular bone is a straight, strong, tubular bone that is not critical for weight-bearing or function of the leg.

Composition  Bone only, osteocutaneous, osteomyocutaneous.

Size  Bone: 25 cm; skin: 25 cm long, 3 cm wide, with primary closure.

Arterial Anatomy

Dominant Pedicle  Peroneal artery

Regional Source  Posterior tibial artery.

Length  4 cm.

Diameter  1.5 to 2.5 mm.

Location  The artery descends behind the fascia covering the tibialis posterior muscle as it courses laterally toward the fibula and then passes anterior to the flexor hallucis longus muscles. Throughout its course, it provides multiple segmental vessels to the bone. At its midpoint on the fibula, there is a nutrient artery. The peroneal artery terminates distally, just inferior to the lateral malleolus as the lateral calcaneal artery.

Minor Pedicle  Lateral inferior genicular artery

Regional Source  Popliteal artery.

Length  3 cm.

Diameter  1.5 to 2 mm.

Location  The lateral inferior genicular artery arises from the popliteal artery and courses toward the fibular head, supplying the head and the capsule of the fibula and joint.

Minor Pedicle  Anterior tibial perforator

Regional Source  Anterior tibial artery.

Length  2 cm.

Diameter  1 to 2 mm.

Location  The anterior tibial artery courses from a posterior-anterior direction, crossing the superior border of the interosseous membrane, then entering the anterior compartment. Small contributions from this vessel are present proximally and can contribute to the blood supply to the fibular head and neck.

Venous Anatomy

The peroneal artery is accompanied by venae comitantes. These vessels have good size with diameters up to 3.5 mm. Despite shortcomings in the arterial length, the vein can be harvested at greater length, because sacrifice of larger venous branches is not critical to perfusion of the distal leg. This can be useful when arterial and venous anastomoses are not performed directly at the same site, such as in head and neck reconstruction. Venous drainage of the lateral inferior genicular artery and anterior tibial artery is via small venae comitantes vessels.

Nerve Supply

Sensory  Superficial peroneal nerve. Although this nerve supplies the skin in situ, this flap is not commonly harvested as a sensate flap.
VASCULAR ANATOMY OF THE FIBULA FLAP

Fig. 13A-2

Dominant pedicle: Peroneal artery (D)
Minor pedicle: Periosteal branches and muscular branches at muscle origin site from fibula (m)
n, Nutrient artery
Fig. 13A-2

**Dominant pedicle:** Peroneal artery (D)

**Minor pedicle:** Anterior tibial arterial branch (m)

f, Fibula; v, fasciocutaneous vessel
FLAP HARVEST

Design and Markings
The fibula can be palpated and marked at its head and the lateral malleolar component. The posterior border of the bone is marked as the center point for a skin paddle, which is carried with the flap. Flap widths greater than 2 or 3 cm will require skin grafting.

Patient Positioning
The patient is placed in the supine or lateral decubitus position.

GUIDE TO FLAP DISSECTION
For a bone-only flap, an incision is made along the length of the fibula, extending from the head to within a few centimeters of the lateral malleolus. The lateral compartment muscles (the peroneus longus and peroneus brevis) are visualized.
These lateral compartment muscles are then separated from the fibula, leaving a 3 mm cuff of muscle adjacent to the bone. This allows perfusion to the periosteum. Next, the anterior compartment muscles, including the tibialis anterior, external extensor digitorum longus, and extensor hallucis longus are identified and dissected from the fibula and retracted. A 3 mm cuff of muscle is again left attached to the fibula. The interosseous membrane is divided along its length. The surgeon then moves to the superficial posterior compartment, where the gastrocnemius and soleus muscles are identified. A cuff of soleus muscle is left attached to the fibula.
Proximal and distal osteotomies are performed. It is essential to identify and preserve the common peroneal nerve as it runs around the neck of the fibula. This marks the location for the proximal osteotomy; the higher the osteotomy, the easier access will be for dissection of the pedicle. Similarly, even if only a small piece of bone is needed, resection of at least 10 cm of bone is planned and a distal osteotomy made. This larger aperture will aid in dissection of the pedicle.

Distally, the flexor hallucis longus muscle is identified and divided. The continuation of the peroneal vessels is visualized and ligated. This will aid in locating the vessels during dissection.
Bone clamps are applied to the bone and the bone is distracted out of the leg. This presents the tibialis posterior muscle, which is a bipennate muscle. This muscle is divided; the peroneal vessels are carefully spared. The distal osteotomy should not extend any closer than within 6 cm of the lateral malleolus to maintain ankle stability. Dissection is carried proximally to gain length to the peroneal vessels. Once the tibioperoneal trunk is visualized, the length of the peroneal artery that can be harvested is set.

The anterior tibial artery must not be injured or occluded, because it supplies the distal leg. It is a matter of the surgeon's preference as to how much of the dissection is done under tourniquet control. The entire dissection can be completed if done in a timely fashion with a tourniquet, aiding visualization and not compromising ultimate graft survival.
FLAP VARIANTS

- Osteocutaneous flap
- Osteomuscular flap
- Epiphyseal transfer

Osteocutaneous Flap
The design of the skin flap planned is over the posterior border of the fibula. A handheld Doppler probe can be used to confirm the location of the perforators from the intermuscular septum. The skin island will extend superiorly to the fibular head and as far distally as within 6 cm of the lateral malleolus. The width of the skin island may be large (up to 14 cm), although this would require skin grafting of the donor site. When 2 to 3 cm of width is required, primary closure may be obtainable.

Initially the anterior incision is made and deepened down to the muscular fascia. An incision through the fascia is performed, with dissection toward the intermuscular septum. The skin island is elevated off the tibialis anterior, the extensor digitorum longus muscles of the anterior compartment, then the peroneus longus and brevis muscles of the posterior aspect of the fibula. Posteriorly, the skin island is elevated off the lateral gastrocnemius and soleus muscles to the posterior edge of the fibula.

The remainder of the dissection is similar to that described for a vascularized fibula-only flap. Special care is taken in this case to preserve the septocutaneous pedicles that originate from the peroneal artery and run to the skin paddle. A small cuff of soleus may be required to help maintain these perforators.
Lengthening of the pedicle of the fibula flap can be accomplished by locating the skin paddle more distally in the leg and by subperiosteal dissection of tissues off of the fibula, using the more distal fibular bone for the reconstruction and removing the proximal bone.
Osteomuscular Flap

The soleus muscle is divided by a sagittal septum, dividing it into medial and lateral parts. The lateral portion is attached to the upper third of the fibula posteriorly and is supplied by the peroneal artery. The soleus can be carried with the fibula flap and used for soft tissue cover or fill. The medial hemisoleus remains functional, vascularized by the posterior tibial vessels.
Epiphyseal Transfer

The lateral descending genicular artery arises from the popliteal artery and courses toward the fibular head, supplying it and the capsule. Although the peroneal artery provides periosteal and endosteal supply to the diaphysis and the metaphysis, this blood supply does not reach the epiphysis, and, therefore, if the epiphyseal area of the fibular head is required for reconstruction, a flap based on the lateral descending genicular artery is required. Although some blood supply to this area does come from recurrent branches off the anterior tibial system, this pedicle is not usable without secondary grafting or reanastomosis before inset. If the anterior tibial artery is used in reverse fashion, a lengthier pedicle is obtained, and vascularization of the epiphysis is facilitated.

A skin incision is made obliquely over the fibular head, then longitudinally anterior to the fibula.
Dissection proceeds through the skin and fascia between the extensor digitorum longus muscle and the anterior tibialis muscle. Exposing the anterior tibial vessel proximally, the peroneus longus and extensor digitorum longus are sharply detached from their insertion approximately 1 cm from the bone.

![Fig. 13A-7](image)

C and D, Dissection of the peroneus longus and extensor digitorum longus, which are sharply detached 1 cm distal to their proximal insertion. The peroneal nerve is the landmark indicating the level.

The peroneal nerve is identified and spared. The epiphyseal branch of the anterior tibial artery is seen crossing superficial to the motor branch of the peroneal nerve. Next, the interosseous membrane is detached from the lateral surface of the tibia. An osteotomy distal to the bone is performed. The tourniquet is released, and bleeding should be observed for both diaphysis and epiphysis.

![Final dissection of fibula flap with epiphysis based on reverse anterior tibial vessels](image)
Proximally, a stump of the anterior tibial artery is too short and cumbersome for anastomosis and a vein graft is required. More commonly, a reverse-flow model is used, and the redundant distal tibial vessels can be used to vascularize the bone.

**ARC OF ROTATION**

**Bone Flap**

With dissection of the pedicle to its source, the bone of the fibula is easily transferred as an ipsilateral transfer for tibial reconstruction.
FLAP TRANSFER

Standard Flap
When securing the fibula in its new tibial position, the surgeon must exercise care so that there is no kinking or compression of the vascular pedicle.

Free Flap
In a free flap, the standard microsurgical principles are adhered to. Osteotomies, if required in the fibula flap, are performed before reanastomosis or while still attached at the leg. Next, osteosynthesis is performed; this will allow inset decisions to be made regarding skin or muscle that may be carried with the flap and prevent injury to the microsurgical anastomosis, which is performed last.

FLAP INSET

Bony Inset
Standard AO principles are used for osteosynthesis. Care is taken not to disturb the microsurgical anastomosis. For flaps containing skin, muscle, and bone, more complex three-dimensional planning must be considered. If an osteosynthesis of the bone needs coverage, the skin paddle and its septum or a portion of the soleus or flexor hallucis longus muscle should be used to cover this area if tissues are deficient in the recipient site. For head and neck or intraoral use, a skin paddle is recommended, since the amount of tissue needed for a watertight closure is often underestimated once resection of tumor or release of scarring has been performed. Often a skin paddle can be taken and used as an external monitor so that the vascularity of the underlying flap can be monitored, and this can be removed secondarily.

DONOR SITE CLOSURE
Flaps that harvest skin and exceed 3 to 4 cm in width will require skin grafting of the donor site.
CLINICAL APPLICATIONS
This 29-year-old woman had fibrous dysplasia of the right mandible; local therapy failed, and she underwent aggressive resection and reconstruction with a fibula free flap.

Fig. 13A-9  A, This three-dimensional CT scan shows involvement from the symphysis to the mandibular angle, which was resected. B, The design of the free fibular flap, with a skin paddle for intraoral lining and monitoring postoperatively. This design allowed primary closure of the donor site. C, This lateral skull film shows the osteosynthesis. D and E, Lateral and AP views 2 months postoperatively, demonstrating good cosmesis and function. (Case supplied by MRZ.)
This 38-year-old woman with a left alveolar ridge squamous cell carcinoma required a partial maxillectomy and underwent reconstruction with a free fibular flap.

**Fig. 13A-10**  
A, MRI revealing the destruction of the maxillary alveolus on the left by cancer.  
B, Partial maxillectomy specimen.  
C, Fibular flap design.  
D, The fibular bone was double-barreled for maxillary reconstruction to replace the resected bony hemipalate. The skin paddle was used to close the intraoral defect. Note that the initial reconstruction is bulky.  
E, The reconstruction is seen 2 months postoperatively. As is often the case with the maxilla, the flap has filled in the dead space and contoured nicely without the need for revision.  
F, Lateral view with normal midface projection.  
G, Donor site scar at 2 months. (Case supplied by MRZ.)
This 10-year-old boy sustained a gunshot wound to the maxilla, leaving him with an oro-nasal fistula and bone loss without upper jaw and dentition centrally.

Fig. 13A-11 A. The intraoral defect is seen, with bone loss and a fistula. B. The fibula flap was harvested and some flexor hallucis longus muscle was taken with the flap. Osteotomies and osteosynthesis were performed before flap inset. C. Because this patient was going to need osteointegration for an anterior appliance, the flexor hallucis longus was used for intraoral closure, rather than the skin paddle of the fibula flap. D. The intraoral muscle will remucosalize and atrophy significantly, seen here at only 3 weeks postoperatively. This mucosalized surface is required for osteointegration; this avoided the need for a procedure to debulk an intraoral skin paddle and to place a buccal graft to prepare for integration. E. The donor site scar is acceptable. (Case supplied by MRZ.)
This 55-year-old woman sustained severe radiation damage from treatment of her intraoral squamous cell carcinoma. She presented with intractable lymphedema of her chin pad and exposure of previously placed mandibular reconstruction plates with osteoradionecrosis of the mandible.

![Images of preoperative and postoperative views of the patient's lymphedema and neck contracture.](A) Preoperative lateral view of the patient's lymphedema and her contracted neck, with restricted neck extension. (B) Intraoral plate exposure, with contracted and scarred mucosa. The patient underwent resection of the mandible from angle to angle. (C) Flap dissected and ready for transfer. The skin paddle was used for intraoral lining, while the hemisoleus was used for resurfacing the neck. (D) After release of the neck contracture and inset of the hemisoleus. The muscle was skin grafted. (E) Postoperative view of the healed skin graft and released neck. (F) Intraoral view of the healed fibular skin paddle at 2 months postoperatively. (Case supplied by MRZ.)
This 45-year-old man had a synchronous left tongue squamous cell carcinoma, T3N0M0, and right lower gum cancer, T2N0M0. The defects following wide excision and marginal mandibulectomy were the entire tongue, floor of the mouth, and right buccal area.

**Fig. 13A-13**  
A, An anterolateral thigh myocutaneous flap was designed and reconstruction was performed; the flap measured 22 by 8 cm.  
B, Subsequently the patient developed osteoradionecrosis of the right residual mandible 1 year after radiation therapy. After a segmental mandibulectomy, the defects were 4 by 2 cm of intraoral lining, 5 cm of mandible, and 7 by 4 cm of external cheek. A fibular osteoseptocutaneous flap including 5 cm of bone and two separate skin paddles measuring 5 by 3 cm and 8 by 5 cm was harvested for the composite mandibular reconstruction. The left superior thyroid artery and external jugular vein were used as the recipient vessels. The soleus muscle, which was based on the myocutaneous perforator of the proximal pedicle, was not harvested for the coverage of the fibula and plate, because it could not reach the desired inset area. The flap survived in its entirety with an ischemia time of 194 minutes.  
C, At 12-month follow-up, the patient had no symptoms or signs of osteoradionecrosis or orocutaneous fistula, but was still fed with a tube because of a previous total glossectomy. (Case courtesy Ming-Huei Cheng, MD.)
This 54-year-old man had a right buccal squamous cell carcinoma, T4aN1M0, and underwent wide excision, which resulted in a compound mandibular defect and partial maxillary defects.

**Fig. 13A-14**  
A, The patient is shown undergoing wide excision of a right buccal squamous cell carcinoma. B, A large skin paddle was designed and split into two parts in a chimeric fashion, because more than one perforator could be recruited into the fibular flap. The lateral subunit of soleus was elevated and based on a separate myocutaneous perforator as the osteomyocutaneous peroneal artery combined flap.
Fig. 13A-14  C and D, When there are no sizable septocutaneous perforators during fibular flap dissection despite preoperative Doppler mapping one may convert the osteocutaneous fibular flap to an osseous flap intraoperatively. E, A 15 by 9 cm anterolateral thigh myocutaneous flap with 12 by 8 cm of vastus lateralis was harvested for intraoral lining and obliteration of the maxillary sinus. F, At 2-year follow-up, the patient was satisfied with the functional and cosmetic outcome of the reconstruction. G, This Panorex view shows good reconstructed mandibular alignment with fibular bone and reconstruction plate. (Case courtesy Ming-Huei Cheng, MD.)
This 50-year-old woman had malocclusion and left compound mandibular defects as a result of wide excision of an osteosarcoma of the left mandible and subsequent radiation therapy 20 years earlier.

Fig. 13A-15  A and B, AP and lateral preoperative views of the patient. C, Preoperative Panorex view. Note the left mandibular segmental defect and malocclusion that resulted from the unstable residual mandible. D, This three-dimensional CT scan clearly demonstrates the left mandibular segmental defect and malocclusion. E, An osteomyocutaneous peroneal artery combined flap with 12 by 5 cm of skin and 6 by 3 by 2 cm of soleus muscle was harvested for reconstruction of the left mandible and external cheek.
Two fibular segments with a total length of 8 cm were fixed to the reconstruction plate after the temporary intermaxillary fixation. The left superior thyroid vessels were used as the recipient site. The vessels were found to be fibrotic and were sequentially resected until healthy intima and rigorous spurting were noted. Vein grafts of 6 cm and 7 cm in length were used to bridge both arterial and venous anastomoses, respectively. The ischemia time was 6 hours. The soleus muscle was flipped over on top of the reconstruction plate for plate protection and volume augmentation. The skin paddle was used for cheek coverage. No complications were encountered. G and H, The patient underwent two revisions for deepithelialization and fat grafting for volume augmentation and better cosmesis. At 20-month follow-up, the patient was satisfied with the functional and cosmetic results. I, A Panorex view and J, a three-dimensional CT scan show acceptable occlusion and good reconstructed mandibular alignment with fibular bone and reconstruction plate. (Case courtesy Ming-Huei Cheng, MD.)
This 7-year-old boy had an osteogenic sarcoma located in the proximal epiphysis of the left humerus.

Fig. 13A-16 A and B, A radiograph and MRI showed massive involvement of the diaphysis as well. C, The wide margin resection included the epiphysis and the proximal two thirds of the diaphysis. D, After transfer of the fibula, the joint was stabilized using half of the biceps femoris tendon, which was woven in the residual capsule. E, Bone fixation was achieved with a reconstruction plate and a few screws. This provides a very elastic implant that prevents stress fractures.
Fig. 13A-16  F, The overall growth of the transferred fibula after 3 years has been 2.9 cm. G and H, The patient’s range of motion is demonstrated at 3-year follow-up. Some functional impairment has resulted from oncologic muscle resection. (Case courtesy Marco Innocenti, MD.)
This 8-year-old girl presented with an osteogenic sarcoma located in the distal left radius.

Fig. 13A-17  A, Involvement of the growth plate and epiphysis was evident on MRI. B, Angiography was performed to assess the vascular supply of the proximal fibular epiphysis, and the recurrent epiphyseal branch was visualized. C, The proximal ipsilateral fibula, including a diaphyseal segment 7 cm long, was harvested, based on the anterior tibial artery, and was transferred to the recipient site. A step-cut osteotomy was performed and bone fixation was achieved by means of three lag screws. The overall growth after 4 years has been 3.4 cm. D and E, Near-normal range of motion of the wrist has been recovered in all planes. (Case courtesy Marco Innocenti, MD.)
Pearls and Pitfalls

- The fibula is the most used donor site for vascular bone grafts in the body because of its low morbidity and ease of harvest.
- The lower 6 to 8 cm of the fibula should be preserved to ensure stability of the ankle mortise.
- A preoperative arteriogram is recommended if the dorsalis pedis and posterior tibial pulses are not palpable. This is essential after traumatic injury to the leg.
- When soft tissue cover is inadequate or the recipient site’s needs are not clearly identified, the lateral hemisoleus can be carried with the flap. This can always be removed later at inset if it is not needed.
- When the epiphysis of the fibula is required, the blood supply through the anterior tibial system should be used. The peroneal blood supply is not reliable in this area.
- In children younger than 9 years of age, removal of the fibula may lead to ankle valgus, and should be managed expectantly.

EXPERT COMMENTARY
Ming-Huei Cheng, Jung-Ju Huang

Indications
The fibula flap is indicated for reconstruction of the mandible, maxilla, tibia, femur shaft and head, humerus, radius, ulna, and spine. The defects may result from wide excision of malignant tumors, trauma, gun shot injury, and congenital anomalies.

Advantages and Limitations
There are a number of advantages to the use of the fibula flap. The bone quality is excellent and will fulfill the function of weight-bearing in long bone and mandibular reconstructions. The flap offers a long pedicle length: up to 15 cm can be obtained when the pedicle is detached from the proximal bone segment (although in doing so the proximal bone segment becomes nonvascularized and is generally discarded). A double-barrel configuration with resection of a short, intervening segment can be designed to achieve better bony height and greater weight-bearing tolerance. A large skin paddle can be harvested and split into two parts in a chimeric fashion when more than one perforator can be recruited into the flap (Fig. 13A–18).
In addition, part of the lateral subunit of soleus can be elevated and based on a separate myocutaneous perforator as the osteomyocutaneous peroneal artery combined flap\textsuperscript{1,2} which may cover the reconstruction plate to decrease the risks of plate exposure after subsequent radiation. It also helps to obliterate the dead space, decreasing the risks of hematoma and infection, and improving contour. Finally, an osteointegrating dental implant may be applied in single-stage for benign cases for total rehabilitation.

Although some surgeons may have concerns with the reliability of the skin paddle, it is usually reliable if the septocutaneous perforators are included with delicate dissection. In the uncommon scenario in which there are no sizable septocutaneous perforators (Fig. 13A-19) or if the perforators originate from the posterior tibial artery, one may convert the osteocutaneous fibula flap to an osseous flap intraoperatively (Fig. 13A-20) and harvest another cutaneous flap for soft tissue coverage. Alternatively, one can suture the skin paddle back and attempt the osteocutaneous fibula flap from the contralateral leg.

**Anatomic Considerations**

The fibula is triangular in shape in the coronal plane. The pedicle, (the peroneal artery), is located on the posteromedial aspect. The septocutaneous perforators travel along the posterior crural septum. The lateral aspect of the fibula bone is the preferred surface for plating and screw insertion, with minimal risk of injury to the pedicle and the associated perforators. Care should be taken to avoid unfavorable orientations that may increase the risks of kinking or torsion. In general, the pedicle traverses a smoother course when it is directed medially to reach either ipsilateral or contralateral recipient vessels.
Personal Experience and Insights
When performing a free fibular flap, one does not need to be overly concerned about the reach of the pedicle, because the pedicle is generally long and can comfortably reach any of the recipient arteries in the neck, even in a vessel-depleted or irradiated neck. I routinely perform single-vein anastomosis. Therefore, if venous congestion develops, I reexplore and augment the outflow by creating an additional venous anastomosis. If the existing vein is thrombosed and remains insufficient after thrombectomy, I recommend complete replacement with the other venous anastomosis. If the skin paddle is small, leeching is useful to phlebotomize the flap. It is not uncommon for a hematoma to form secondary to bleeding from the osteotomy sites. Therefore adequate drain placement in the dependent sites is essential.

Recommendations
Planning
Although the free fibula flap is a relatively long procedure, I do not recommend the two-team approach, as is frequently performed by many surgeons. I think it is critical to accurately assess the defect after the resection is completed. I trim either a sterile paper or a green towel to create templates for the soft tissue coverage. The paper ruler that comes with the surgical marker is a simple, convenient, and powerful tool to use as a template for determining osteotomy sites, angles, and bone lengths (Fig. 13A-21). Note in this case that redundant periosteum around the pedicle was discarded to produce a longer pedicle and to decrease the potential for compression of the pedicle.

Temporary mandibulomaxillary fixation is important to preserve preoperative occlusion before the reconstruction plate is applied to the residual mandibular bones. In my experience, the complications are significantly increased when the right mandible is reconstructed using a left fibula flap. I prefer to use the left fibula flap for left mandibular reconstruction with a skin paddle for intraoral lining, and vice versa. Preoperative angiography is not necessary; handheld Doppler mapping of the perforators is sufficient. Generally speaking, the perforators from the middle and distal third of the leg are septocutaneous in nature, while the ones from the proximal third are myocutaneous (see Fig. 13A-18).

Continued
**Technique**

The posterior margin of the fibula bone should be marked accurately for reliable mapping of the septocutaneous perforators preoperatively (Fig. 13A-22). The posterior margin (red arrows) is incised suprafascially until the sural nerve (Fig. 13A-23, yellow arrow) and lesser saphenous vein (blue arrow) are preserved. I prefer the anterior approach (Fig. 13A-23).

With the anterior approach, the dissection is initially suprafascial. Preserving fascial coverage over exposed tendon (the peroneus longus) facilitates the take of the skin graft. Once the dissection progresses posterior to the peroneus longus tendon, the dissection is deepened to a subfascial plane. On confirmation of adequate septocutaneous perforators (see Fig. 13A-23, red arrows), the posterior skin margin is incised. The sural nerve (yellow arrow) and lesser saphenous vein (blue arrow) are usually preserved. The osteotomies are performed when the peroneus longus and brevis are detached to allow posterolateral mobilization of the fibula for better exposure of the extensors in the anterior compartment. I do not recommend inclusion of the flexor hallucis longus to avoid pedicle injury. In my opinion, the flexor hallucis longus has an indispensible function, and sacrificing it causes great toe flexion contracture.
The osteotomies of the fibula bone are carried out on the back table after division of the pedicle (see Fig. 13A-21). The complications, especially partial skin loss, are not significantly increased if the ischemia time is kept to less than 5 hours. It is more important that the surgeon take time to perform precise osteotomies, remove redundant periosteum around the pedicle (skeletonization), and inset the flap before the microsurgical anastomoses. The artery anastomosis is performed before the venous one to ensure adequate backflow from the vein. The flexor hallucis longus should be sutured to the interosseous membrane to decrease the postoperative flexion contracture of great toe when the donor site is closed. If the donor skin defect is greater than 3 cm, it is better to place a split-thickness skin graft on top to avoid compartment syndrome.

**Postoperative Care**
No anticoagulant is prescribed routinely; there is usually some oozing from the osteotomy sites. But low-dose heparin 5000 units per day may be indicated to prevent deep vein thrombosis or when any perfusion is compromised in the flap.

**Complications: Avoidance and Treatment**
The partial necrosis of skin paddle is the most common complication. Any tension on the skin paddle should be avoided, because the septocutaneous perforators cannot tolerate the tension well. Removal of stitches and reinset of the flap may be helpful when the perforators are tenting, kinking, or twisted.

**Take-Away Messages**
The fibula flap is perceived by many surgeons as a difficult procedure. I tend to think of it as a long procedure, but not necessarily difficult. Often the perceived difficulty originates from inexperience. One begins to appreciate the flap’s versatility and elegance after mastering the initial learning curve. I considered the following the most important considerations in performing a free fibula flap: thorough knowledge of the anatomy of the fibula flap; precise flap design based on the defect and available recipient vessels; meticulous perforator dissection; tension-free inset of the skin paddle; and proper pedicle orientation.

**References**
EXPERT COMMENTARY
Marco Innocenti

Indications
An autologous vascularized epiphyseal transplant from the proximal fibula is the only available option when performing epiphyseal reconstruction in children. The key feature of such a procedure is the ability to reconstruct the bone loss while simultaneously restoring the growth potential. The feasibility of the technique depends on adequate blood supply both to the growth plate and to the diaphysis; a failure in revascularization actually leads to premature fusion of the growth plate and possible nonunion with the host bone.

Current indications for vascularized epiphyseal transfer include trauma, tumor, and congenital disorders involving the growth plate of a long bone in children. The proximal humerus and distal radius can be optimally reconstructed with such a procedure, but the technique has occasionally been used in cases of custom reconstruction of lower limb joints, such as the hip and knee. In our series of 30 cases, more than 70% of patients have had consistent and predictable axial growth after the transfer and all the grafts, but one healed with the host bone and had hypertrophy.

Advantages and Limitations
Neither a prosthesis nor a nonvascularized graft is actually able to replace the damaged epiphysis while at the same time restoring growth potential. A vascularized transfer of the proximal epiphysis of the fibula, along with a variable amount of the adjoining diaphysis, is definitely the most effective solution for dealing with upper limb bone defects of the distal radius or proximal humerus in pediatric patients. The ability to preserve the growth potential and significant morphologic remodeling are the most important advantages related to this procedure.

However, proximal fibula epiphyseal transplantation is not complication free. The harvesting technique is relatively demanding, and many details must be taken into account. Among them, the ischemia time seems to be particularly relevant to maintain physiologic growth after transfer; therefore revascularization must be as prompt as possible. Prevention of damage to the peroneal nerve, which is strictly connected with the anterior tibial vascular bundle, is critical during dissection. Nevertheless, even in a meticulous dissection, a transient palsy of the muscles of the anterior compartment is a relatively frequent finding, and this should be taken into account in children who are learning to walk. In such a circumstance, it is probably advisable to postpone the procedure for a few months.

Anatomic Considerations
Failure of axial growth and premature fusion of the physis are some of the potential complications that may be related to the choice of the pedicle. The upper fibular epiphysis is supplied by three small arteries: the inferior genicular artery, a recurrent branch of the anterior tibial artery, and a nonconstant unnamed artery directly rising from the popliteal artery. Much of the early published reports describe the use of the peroneal artery either alone or combined with an epiphyseal artery. The grafts based on the peroneal artery alone had an unpredictable outcome, and the majority of them failed to achieve acceptable growth. On the other hand, the double-pedicled grafts in which the peroneal artery and either the descending genicular artery or the recurrent branch of the anterior tibial artery are harvested are technically difficult, because they require multiple anastomoses and vein grafts. Operative time is increased, adding the risk of thrombosis.
In 1988 Taylor reported his anatomic investigations on the proximal fibula blood supply, confirming the role of the anterior tibial artery in the vascularity of the fibular growth plate and demonstrating that sufficient blood supply can be provided to the proximal diaphysis by small musculoperiosteal branches arising from the same artery. Therefore the anterior tibial artery may be used as the vascular pedicle for a distant transfer of such a graft if both the epiphyseal vessel and the delicate periosteal vascular network are preserved during the dissection.

**Personal Experience and Insights**

We performed this procedure on 30 patients ranging from 2 to 11 years of age. Nineteen patients had malignant bone tumors involving the proximal humerus, the distal radius in eight, and the hip in three. According to our findings, the growth trend that can be expected after the transplant ranges from 0.7 to 1.4 cm per year. The factors that might interfere with the growth of the grafts can be summarized as follows:

- **Age of the patient:** The growth potential is a function of age, and it can change as long as skeletal maturity has not been reached.
- **Recipient anatomic area:** The new heterotopic location influences the growth by means of mechanical and humoral factors.
- **Blood supply:** The quality and quantity of the blood supply and their variations have an inevitable impact on growth.
- **Adjuvant chemotherapy:** Chemotherapy is routinely administered preoperatively and postoperatively in cases of bone sarcoma. Inhibition of skeletal growth has been reported as one of the side effects of such therapy.

From a functional standpoint, excellent results are usually achieved in distal radius reconstruction. In our series, all patients recovered a nearly normal range of motion on all planes, and the wrist was pain free and stable. Neither axial deviation nor subluxation of the caput ulnae has been observed. The articular surface underwent significant remodeling, governed by the loading stresses present in the new location, and developed a concave surface that improved stability and range of motion.

Proximal humerus reconstruction provides less exciting results because of the anatomic mismatch between the fibular head and glenoid cavity. In addition, all the tumor cases in our series were complicated by the ablation of a variable amount of the muscles, with negative consequences in active motion. However, acceptable range of motion for daily activities can be expected in all cases, and epiphyseal transplantation maintains its supremacy over conventional techniques in this anatomic region.

**Recommendations**

**Planning**

Some preoperative investigations are essential; angiography is routinely done to confirm the presence of the recurrent epiphyseal branch of the anterior tibial artery. In our experience, the feeding vessel to the growth plate was present in 100% of cases. In one case the anterior tibial artery and the peroneal artery had a common origin, but no other anatomic variations have been observed. In tumor cases, an MRI of the affected bone is essential to assess the extent of the tumor and to plan a wide-margin resection. In a massive invasion of the radius, which suggests total resection of the bone, a side-to-side assemblage of the fibula with the ulna should be planned. This option provides satisfactory range of motion of the new radiocarpal joint, but locks pronation and supination.
Technique
Harvesting of the proximal fibula based on the anterior tibial artery vascular network has recently been refined. We modified the original technique described by Taylor in 1988, introducing a reverse-flow model that provides a very long distal vascular pedicle and avoids the use of vein grafts. An anterolateral approach in the space between tibialis anterior and extensor digitorum longus muscles, prolonged proximally and laterally up to the biceps femoris tendon, is chosen to expose the fibula and the vascular pedicle. Great care must be taken in dissecting the peroneal nerve from the anterior tibial vascular bundle and in preserving the myoperiosteal branches to the diaphysis of the fibula. Direct dissection of the epiphyseal recurrent branch is not recommended because of the dimension of the artery and the high risk of injury. The small vessel must be protected by a muscular cuff, including the portion of extensor digitorum longus and peroneus longus muscles that is proximal to the intersection of peroneal nerve. A strip of biceps femoris tendon is included in the harvest and is used for soft tissue repair in the recipient site.

Distal radius reconstruction is facilitated by the perfect correspondence in size with the host bone. Bone fixation is usually achieved with plates and screws, and the pedicle is anastomosed end-to-end either to the anterior interosseous or radial arteries and the cephalic vein. Bleeding from the muscular cuff that surrounds the epiphysis after microvascular repair indicates restoration of flow to the growth plate. The radiocarpal joint is stabilized using the biceps femoris tendon strip, which is woven in the residual distal capsule.

The diameter of the humerus is approximately double that of the fibula, and this anatomic mismatch suggests an intramedullary location of a portion of the fibular shaft. To provide an elastic implant, the subsequent osteosynthesis should be achieved by a long locking compression plate with unicortical screws. The preferred recipient vessels are the deep humeral artery and vein. The glenohumeral capsule and rotator cuff are gently sutured around the fibular epiphysis to stabilize the joint.

The proximal fibular epiphysis may also be used in selected cases of hip reconstruction. We replaced the proximal femur in three children with bone sarcoma using a prefabricated graft consisting of a segment of massive allograft and autologous proximal fibula. The head of the femoral allograft was resected and the medullary canal reamed to place the vascularized fibula in the medullary cavity in a concentrical fashion. After rigid bone fixation, the epiphysis was reduced in its anatomic location and anastomosed to the recipient vessels. The aim of the procedure was to provide an adequate bone stock with the allograft and the potential for growth and joint function with the fibula. However, only one patient of three had a satisfactory outcome, with preservation of growth, integration between the vascularized fibula and allograft, and full weight-bearing after 3 years.

Postoperative Care
Adequate protection of the donor and recipient sites must be provided. This is particularly important in dealing with infants, who are less compliant than adults and more difficult to manage. At the donor site, an above-knee cast including the foot should be placed both to stabilize the knee joint, protecting the lateral collateral ligament reconstruction, and to prevent footdrop, which is almost the rule during the first postoperative weeks. The cast remains in place for 1 month. In a forearm reconstruction, a below-elbow cast is usually sufficient. After 4 weeks it may be replaced with a splint and rehabilitation may begin. In a humerus reconstruction, torque stress is the most dangerous mechanical force that may interfere with healing and eventually lead to fracture. For this reason, a Desault brace should be applied for 1 month, and subsequent rehabilitation must be particularly careful.
Complications
Complications have been observed both at the donor and recipient sites. Instability of the knee joint may be one of the complications expected in the donor area. However, meticulous reconstruction of the lateral collateral ligament can usually prevent this. By contrast, injuries to the motor branches of the peroneal nerve are very difficult to avoid. In a section of a motor branch, direct neurotization or neurorrhaphy is recommended to reduce the likelihood of a permanent palsy of the muscles supplied by this nerve.

Fractures are more likely to occur in a humeral reconstruction as a result of excessive mechanical stresses. In our experience, the use of more elastic implants significantly reduced the incidence of fractures in the transferred bones.

Subacromial displacement of the fibular physis is a frequent complication related to anatomic mismatch and subsequent reconstructive problems. Although this condition does not interfere much with the final functional outcome, it should be prevented to ensure the quality of the reconstruction.

A failure in longitudinal growth is a major complication that probably results from damage to the recurrent epiphyseal artery that supplies the growth plate after the transfer to heterotopic location.

Bibliography With Key Annotations

Mandibular reconstruction with the microvascular free fibula flap (MFF) is an elegant solution to restore the anatomic arch, oral functions, and facial esthetics. However, the thin cutaneous tissue, the thickness of subcutaneous tissues, the absence of a pelvilingual and vestibular groove, and the fragility of soft tissues complicate dental prosthetic stabilization. Implants may restore prosthetic functionality. This article presented the results of a retrospective study of oral reconstruction with implant-supported prostheses after mandibular reconstruction with the MFF. Twenty-three patients underwent mandibular reconstruction. Fourteen patients underwent radiotherapy before reconstruction. Mandibular osteoradionecrosis was the indication for reconstruction in seven patients. Seventy-five implants were placed, with an 80% success rate. Occlusion was judged “satisfactory” for 69.6% of patients. For 57% of patients, the quality of surrounding soft tissues was judged “satisfactory.” For 74% of patients, oral rehabilitation was “satisfactory.” The authors concluded that the implant-supported prosthesis after MFF mandibular reconstruction gives satisfactory results despite the thickness and mobility of soft tissues, and despite scar contracture and the absence of keratinization.


Following internal hemipelvectomy, young patients desire a durable, pain-free pelvic reconstruction. However, such reconstruction is extremely challenging, and patients often are left with less-than-optimal gait, including a limp, leg-length discrepancy, or leg instability. This article presented an innovative method for pelvic ring reconstruction using a vascularized double-strut fibular bone flap that provides a stable pelvis and allows recovery of normal or near-normal gait. The authors presented six sarcoma patients who underwent internal hemipelvectomy and pelvic ring reconstruction with a vascularized double-strut fibular bone flap. The length of each strut was 7 to 12 cm. All bone flaps survived. Mean follow-up was 18 months. Radiographic evidence of bone bridging was seen at a mean of 2.5 months. The mean time to ambulation without assistance was 8 months. One patient died as a result
The remaining five patients were ambulatory with a mild limp or no limp. The authors concluded that use of a vascularized double-strut fibular bone flap for pelvic ring reconstruction is effective in facilitating early ambulation and restoring normal to near-normal gait in patients who have undergone internal hemipelvectomy.


This article reported the results of using a free flap procedure followed by ipsilateral vascularized fibular transposition (IVFT) for reconstruction of composite tibial defects. Ten patients underwent a free flap procedure followed by IVFT and plating. The mean size of the flaps was 12.1 by 6 cm. The mean length of bone defect was 5.35 cm. IVFT was performed 4.3 months after the free flap. Patients were followed for an average of 3.4 years. All flaps survived. There were neither stress fractures of the transferred fibula nor recurrent infections. One patient had a medial angulation of 8 degrees in the reconstructed tibia but had no difficulties in activities of daily living. At last follow-up, all patients were able to walk without an assist device and were satisfied with the preservation of the injured lower extremity. The authors stated that free flap procedures followed by IVFT for the treatment of composite tibial defects may reduce complications at the recipient site and infections, such as osteomyelitis. In this series, the authors' plating technique combined with IVFT allowed bone union without additional operations or stress fractures. The authors concluded that staged free flap and IVFT is useful for the treatment of composite segmental tibial defects.


Although vascularized bone grafts have become well accepted for adult patients, especially following ablative head and neck procedures, few long-term studies exist of the use of these grafts in pediatric patients. The authors reviewed the outcomes of 18 free fibula grafts in 16 patients aged 10 months to 21 years (mean 12 years), with an average follow-up of 5 years. Eleven patients had cancer-related defects, four had craniofacial anomalies, and one had a posttraumatic deformity. All patients with congenital malformations had been followed since birth, and the others had been followed from the time of their original cancer diagnosis or injury. Seven patients underwent irradiation, and seven underwent chemotherapy. The most severe deformities were seen in those with cancer resection and radiation therapy. Most defects were hemimandibular; there was one total mandibular defect (Ewing’s sarcoma). Ten patients had had previous failed nonvascularized bone grafts. Eleven flaps were osteocutaneous with either intraoral or extraoral components; most had multisegmental osteotomy and had one arterial and two venous anastomoses. All free fibula transfers were successful; there were no vascular problems and two minor complications. The authors stated that a number of lessons were learned from careful analysis of this unique group of patients, and an algorithm of pediatric mandibular reconstruction was proposed.


The vascularized free fibula flap has become the most popular reconstruction method after mandibular resection because of adequate bone graft length and the acceptance of dental implants. However, using one fibula bone may produce a height discrepancy between the native mandible and the grafted fibula, resulting in difficulty in fitting conventional dentures or osteointegrated implants. The authors described the reconstruction of segmental mandible defects with the double-barrel fibula flap and denture rehabilitation in seven patients. A donor site fibula corresponding to at least twice the length of the mandibular defect was harvested. Prosthodontic treatment was completed in all patients. Four patients received secondary implant-supported dental reconstruction, and three patients who received radiation after graft surgery had conventional removable partial dentures. The authors reported that microvascular fibula transfers were completely successful, and all skin paddles survived without necrosis.
The original mandibular contour was maintained by a reconstruction plate; all patients were satisfied with the postoperative facial aesthetics and chewing function from the implant-supported denture and removable partial prostheses.


Perfusion of a fibular flap is based on the peroneal artery. To avoid postoperative ischemia of the lower leg after the artery has been sacrificed, adequate perfusion must be ensured preoperatively. Although common anatomic variations and pathologic changes are well recognized, the best way to evaluate the vascular system preoperatively is controversial. The authors reported their attempts to identify anatomic vascular patterns that can jeopardize either the limb or the flap while the fibula is being harvested. They provided a few simple principles for preoperative evaluation. The authors dissected 128 lower legs preserved in formalin and evaluated them for the incidence of vascular anatomic variants; they measured absolute and relative loss of volume. Volume loss from the peroneal artery was considerable, 23%. On two occasions the peroneal artery mimicked the anterior tibial artery in its course to the dorsalis pedis artery at the dorsum of the foot; in four cases the tibial artery arose directly from the peroneal artery; and in five cases only a rudimentary posterior tibial artery could be found. Numerous vascular variants were found in the lower leg, some of which could put the flap or the limb at risk.


In some cases, the fibula osteocutaneous flap may not provide sufficient soft tissue for obliterating dead space after tumor ablation. This article described a modified fibula osteocutaneous flap using a portion of soleus muscle. The authors reported on 20 patients who underwent ablative oral cancer surgery with a mandibular segmental defect. Seventeen cases were mandible complex defects and three were composite defects. The procedure entailed harvest of a chimeric fibula flap with skin paddle and bone segment composed of a sheet of soleus muscle (7 by 4 to 12 by 5 cm) originating from the perforator branch of the peroneal artery. The soleus muscle was used to obliterate the dead space of the mouth floor and cheek-neck area. All flaps survived except one. Donor site assessment revealed a satisfactory outcome without major donor site morbidity. The authors concluded that this refinement in mandibular reconstructive surgery substantially reduces postoperative complications.


This article focused on the combined use of a vascularized fibular flap and massive allograft for intercalary reconstruction after resection of a tibial malignancy. Eight patients underwent reconstruction with an allograft and vascularized fibula following tibia malignancy resection. Patients were examined clinically and radiographically. The average age was 16.5 years. Mean follow-up was 38.4 months. Contralateral free fibula flaps were used in three patients and ipsilateral pedicle fibula flaps in five. The average length of the defect was 11.8 cm; the average length of the fibula flap was 15.9 cm. Primary union was achieved in seven patients. The average time for bone union was 5.8 months at fibula-tibia junction and 14.1 months at the allograft-tibia junction. Five patients had 10 complications. The Musculoskeletal Tumor Society average score was 90.8% at final follow-up. The authors concluded that the intramedullary fibular flap, in combination with massive allografts, provides an excellent option for reconstruction of large bony defects after tibial malignancy extirpation. Ipsilateral pedicle fibula transfer provides a short operative time and avoids donor site complications compared with contralateral free fibula transfer.

A subset of patients with recurrent or second intraoral tumors undergo both primary and secondary mandibular reconstruction using bilateral fibula flaps. This article described indications and outcomes for these patients. The authors presented a retrospective analysis of a prospectively collected database. They reviewed charts to identify demographics, operative features, and functional outcomes. Ten patients underwent mandibular reconstruction with a second fibula flap for recurrent or second oral tumors. The time between flaps averaged 20 months. Bone gap size measured 8 cm after both resections. Eighty percent of secondary resections included the mandibular arch, in contrast to 20% of primary resections. Compared with primary resections, secondary soft tissue defects were larger and more frequently included composite tissues. There were low complication rates and no flap failures after both reconstructions. Functional evaluation showed a greater dependency on supplemental enteral nutrition after the second resection. Five patients died at a median of 12.5 months after the second resection, and the remaining patients survived for a median of 18.6 months. The principal indication for second fibula flaps in mandibular reconstruction is central segment defects in which rigid support is required to prevent sequelae of the Andy Gump deformity. The authors concluded that for lateral resections, the large soft tissue deficits of secondary extirpation can be better served by reconstruction with soft tissue flaps. Second osseous free flaps can be performed safely, but with a significant decline in postoperative oropharyngeal function.


Although the fibula free flap is preferred for bony head and neck reconstruction, donor site morbidity remains a concern. The authors evaluated potential risk factors for complications and whether the type of wound closure and timing of postoperative ambulation had an effect on the development of short- and long-term morbidity. They presented a prospective cohort study of donor site morbidity in 157 consecutive patients who underwent fibula free flap reconstruction for head and neck defects. Perioperative donor site complications occurred in 31.2% of patients, including skin graft loss (15%), cellulitis (10%), wound dehiscence (8%), and abscess (1%). Preoperative chemotherapy was associated with increased complications. No significant difference in complication rates was observed between primary and skin graft wound closure. The timing of ambulation was not related to the development of complications. Long-term morbidities occurred in 17% of patients. Functionally, 96% of patients returned to their preoperative level of ambulatory activity. The authors conclude that fibula free flap harvest is associated with a high rate of complications, but the majority of patients have no long-term functional limitations.


Long segmental bony defects after tumor extirpation can pose difficult problems for the reconstructive surgeon. Capanna and colleagues described a technique that places a free fibular flap within the intramedullary canal of an allograft for reconstruction of large intercalary bony defects. This article described the authors’ long-term follow-up with this technique for the treatment of large segmental bone defects in a pediatric population. They presented seven patients who underwent bony reconstruction with an allograft and vascularized fibular construct. All reconstructions were performed for lower extremity salvage after tumor extirpation. Grafts were evaluated for viability with bone scans 10 days postoperatively. Radiologic and clinical evaluations were performed on all patients. Time to union was recorded through evaluation of plain radiographs. Patients’ charts were evaluated for postoperative complications. The average follow-up time was 36 months. Limb salvage was 100%, with all bone
scans positive at 10 days. The average time to complete bony union of the fibula and allograft to the native bone was 9 months. There were no allograft fractures and no infections. One patient developed nonunion at the donor leg syndesmosis site. All patients returned to ambulation. The authors concluded that intramedullary free fibular flaps in combination with massive bony allografts provide an excellent option in the pediatric population for reconstruction of large bony defects after tumor extirpation.


The dominant blood supply to the head of the fibula and to the growth plate is known to be the anterior tibial artery. The peroneal artery had been used before, among other donor pedicles, for microvascular transfers of this epiphyseal region. This article presented the long-term results of this now-obsolete pedicle and compared them to other reports in the literature. Follow-up was performed in 1996 and in 2003 with six patients who underwent wrist reconstruction in the 1980s. Procedures were performed following one resection of a malignant synovialoma, two traumatic hand amputations, and three radial aplasias. Evaluation was performed with functional and radiographic examinations. Three cases that were examined in 2003 were presented in detail. The authors concluded that if growth plates are closed at the time of procedure, or the transplanted fibula is long enough to ensure anastomotic flow between metaphyseal and epiphyseal vessels, results are good. If any of these two conditions are not fulfilled, vascular supply to the epiphysis is insufficient. Long bone deviation or bone necrosis will result.


The authors reviewed 34 consecutive cases of maxillary reconstruction with the free fibula flap. The main postoperative functional indices, including oral diet, speech, type of dental restoration, and aesthetic results, were evaluated. Postoperative complications occurred in five patients. Recipient site wound infection occurred in two patients, and donor site wound dehiscence occurred in three patients. One patient with donor site wound dehiscence had postoperative lameness. The oral and nasal cavities were separated well by the flap in all patients. The patients were able to take food orally and had no problems with speech intelligibility. Osseointegrated implants were placed in four patients, and complete conventional prostheses were applied in 19 patients. Excellent cosmetic results were obtained in 22 patients. The authors concluded that alveolar arch defects can be reconstructed successfully using free fibula flaps. This procedure also allows dental implant rehabilitation, which can improve the patient's appearance and oral function. The fibula free flap transfer has a high success rate and low perioperative complication rate, making it an ideal choice for maxillary defect reconstruction.


Segmental defects of the distal femur following trauma pose a reconstructive challenge. A stable reconstruction capable of withstanding high forces while allowing early mobility is ideal. The Capanna technique of combining allograft with vascularized bone graft has been described for oncologic resection. This article reported on reconstruction of large traumatic segmental defects of the distal femur using a modified Capanna technique, the “inlay” construct. Three reconstructions were performed for distal femoral segmental loss following trauma. One patient had bilateral reconstructions. Bone defects measuring 11, 9, and 8 cm were reconstructed. Both patients made uneventful recoveries and achieved full weight-bearing without walking aids 6 months after reconstruction. The authors concluded that large segmental traumatic defects of the femur can be successfully reconstructed using segmental allograft with vascularized fibula inlay. This reconstruction provides early mechanical stability, protecting the fibula from fracturing and allowing axial loading of leading bone. The inlay assembly allows a large area of bony contact between allograft and vascularized bone, optimizing healing.

Advancements in microsurgery have contributed to the free fibula flap becoming the workhorse flap for composite mandibular defect reconstruction. This article reported on the qualitative and quantitative analyses of donor site morbidity following suprafascial versus subfascial free fibula flap harvesting. The authors presented a total of 27 free fibular flaps used for mandible reconstruction. Of the 27 flaps, 18 suprafascial and 9 subfascial dissections were performed. A questionnaire was completed by all patients to assess qualitative aspects of donor site morbidity and function. Quantitative studies focused on bilateral isokinetic testing of each patient’s lower extremities by comparing and quantifying the ankle function. For the subfascial group, 42% of patients complained of pain and alteration in sensation. These donor site morbidities within the suprafascial group were negligible. For the subfascial group, the donor leg showed significantly less range of motion in plantar flexion exercises. Comparing the isokinetic examination results of the suprafascial and subfascial groups, a significant decrease in ankle dorsiflexion, plantar flexion, and foot eversion was evident in the subfascial group. The authors concluded that for the suprafascial method of fibular flap harvest, subjective perception of donor site morbidity is relatively low. The authors’ quantitative analysis revealed that this method did not cause decreases in ankle function, and it had superior contour and aesthetic outcomes compared with the conventional, subfascial method.


For malignant tumors of the pelvis, limb salvage surgery is now the treatment of choice, even for patients with advanced tumors. For these patients, pelvic reconstruction is needed to maintain the stability of the pelvis and the spinal column and to allow ambulation. The authors described their experience performing pelvic ring reconstruction in five patients with free double-barreled vascularized fibular grafts after resection of malignant pelvic tumors. The graft was fixed with a fixation plate and screws in three patients and with the Cotrel-Dubousset rod system in two patients. In one patient a pedicled rectus abdominis myocutaneous flap was transferred to repair defects of the skin and underlying soft tissue. The free fibular graft was transferred successfully in four of five patients; however, the graft was removed in one patient because of infection with methicillin-resistant Staphylococcus aureus. After surgery, three of the four patients with successful grafts could walk with full weight-bearing without a walking aid; the fourth patient died as a result of metastases to the lung before walking was attempted. The authors concluded that double-barreled fibular graft is well vascularized and can achieve satisfactory bone union. It is a safe and effective method for reconstructing the pelvic ring. Furthermore, the Cotrel-Dubousset rod system can provide rigid fixation soon after surgery and is useful for early rehabilitation of walking.


The authors evaluated long-term donor site morbidity after harvest of free fibular flaps. From a total of 165 patients, they were able to examine 62 donor regions in 57 patients (33 men and 24 women) 2 to 167 months (mean 45 months) after fibular transfer. Patients’ individual risk factors and any disturbances of healing, and dysfunction of the toes, were recorded. The Kitaoka ankle-hindfoot score was used for evaluation of functional impairment. Thirteen donor regions displayed prolonged wound healing, eight of which needed revision of the wounds. Eight had abnormalities of gait. The median Kitaoka ankle-hindfoot score was 93. In 17 patients, after a follow-up period of 4 months, hammer and claw toes and deficits in dorsal extension of the hallux were assessed. Thirty patients had sensory deficits of the calf and toes. Neither the risk factors recorded nor the factors that indicated disturbance of wound healing or deformities of the toe were significantly associated with the development of functional impairment. In more than three-quarters of the cases, healing was uneventful; however, in
a small number the morbidity at the donor site was severe, forcing the patients to use walking aids. The authors were not able to identify any risk factors for the development of long-term malfunction.


The authors presented 80 consecutive patients undergoing free fibula flap reconstruction. The location, size, and type of perforators were recorded intraoperatively and mapped on the line connecting the fibular head and lateral malleolus. There were 46 male and 34 female patients with a total of 202 perforators. Two discrete groups of perforators could be identified. The proximal perforator was consistently found one third the length and 1.5 cm posterior to the line. The majority of these perforators were myocutaneous. The more clinically useful perforators to support a skin paddle are the distal ones over the third quarter of the fibula. One to three distal perforators were consistently present, grouped as perforators A, B, and C at points 0.51, 0.62, and 0.73 along the line, respectively. Perforators were approximately 3.5 cm apart and 2 cm posterior to the line, and the majority (96 percent) were septocutaneous. The authors concluded that using common anatomic landmarks, a reliable skin paddle can be designed with simplicity and confidence over the third quarter of the fibula. The proximal perforator can be useful as a second skin paddle for through-and-through reconstruction.
ANATOMIC LANDMARKS

| Landmarks | This broad, bipennate muscle occupies the posterior leg deep to the gastrocnemius muscles. |
| Size      | 8 × 28 cm. |
| Origin    | Fibula: Posterior surface of the head of the fibula, posterior surface of the body of the fibula (lateral belly). Tibia: Middle third of the medial border of the tibia (medial belly). |
| Insertion | Calcaneus through the Achilles tendon. Lateral belly is located on the dorsal lateral aspect of the Achilles tendon and the medial belly on the dorsal medial aspect. |
| Function  | Plantar flexion of the foot. |
| Composition | Muscle. |
| Flap Type | Type II. |
| Dominant Pedicles | Branches of the popliteal artery; branches of the posterior tibial artery; branches of the peroneal artery. |
| Minor Pedicle | Segmental branches from the posterior tibial artery. |
| Nerve Supply | Motor: Posterior tibial nerve. |
Section 13B

LEG

Soleus Flap

CLINICAL APPLICATIONS

Regional Use

Middle and distal third of leg
ANATOMY OF THE SOLEUS FLAP

Soleus muscle bony origins and tendinous insertion

Vascular anatomy of soleus muscle

Fig. 13B-1

**Dominant pedicles:** Muscular branches of popliteal artery; proximal two branches of peroneal artery; proximal two branches of posterior tibial artery

**Minor pedicle:** Three or four segmental branches of the posterior tibial artery
ANATOMY

Landmarks
This broad, large, bipennate muscle occupies the posterior leg and lies deep to the gastrocnemius muscle. The muscle has two separate bellies: medial and lateral, with separate origins and blood supply. The muscles are fused at its proximal half and are separated by the midline intramuscular septum in the distal half.

Composition
Muscle.

Size
8 × 28 cm.

Origin
Fibula: Posterior surface of the head of the fibula, posterior surface of the body of the fibula (lateral belly). Tibia: Middle third of the medial border of the tibia (medial belly)

Insertion
Calcaneus through the Achilles tendon. Lateral belly is located on the dorsal lateral aspect of the Achilles tendon and the medial belly on the dorsal medial aspect.

Function
Plantar flexion of the foot. With preservation of the gastrocnemius muscle and the contralateral hemisoleus muscle, this function is preserved.

Arterial Anatomy (Type II)

Dominant Pedicle
Muscular branches of the popliteal artery

Regional Source
Popliteal artery.

Length
1 cm.

Diameter
1 to 1.5 mm.

Location
Uppermost portion of the soleus muscle.

Dominant Pedicle
Proximal branches of the peroneal artery

Regional Source
Peroneal artery.

Length
1 to 2 cm.

Diameter
1 to 2 mm.

Location
Upper third of the muscle (lateral belly).

Dominant Pedicle
Proximal branches of the posterior tibial artery

Regional Source
Posterior tibial artery.

Length
1 to 2 cm.

Diameter
1 to 2 mm.

Location
Upper third of the muscle to the medial belly.

Minor Pedicle
Segmental branches from the posterior tibial artery

Regional Source
Posterior tibial artery.

Length
1 to 1.5 cm.

Diameter
0.5 to 1 mm.

Location
Segmentally located along the medial border of the muscle (medial belly).

Venous Anatomy

Branches of the popliteal artery and posterior tibial artery are accompanied by venae comitantes.

Nerve Supply

Motor
Posterior tibial nerve.
VASCULAR ANATOMY OF THE SOLEUS FLAP

Fig. 13B-2

Dominant pedicles: Muscular branches of popliteal artery ($D_1$); proximal two branches of peroneal artery ($D_2$); proximal two branches of posterior tibial artery ($D_3$)

Minor pedicle: Three or four segmental branches of the posterior tibial artery ($m$)

a, Peroneal artery; p, posterior tibial artery
**FLAP HARVEST**

**Design and Markings**

The soleus muscle can be approached either through an incision 2 cm posterior to the medial edge of the tibia or through a lateral incision 2 cm posterior to the fibular border. Although the blood supply of the skin overlying the soleus is through fasciocutaneous perforators, a myocutaneous flap based on the soleus has limited practical application and therefore its use is not recommended.

![Marking for incision for elevation of more common medial hemisoleus flap](image)

**Patient Positioning**

The patient is placed in the supine position with a tourniquet in place.
GUIDE TO FLAP DISSECTION
For medial exposure, an incision can be made parallel and 2 cm posterior to the tibia, or dissection can occur through an existing wound along the medial border of the tibia.

Dissection proceeds through the skin, and the soleus muscle is identified. Both the gastrocnemius and plantaris tendons lie superficial to the muscle.

Fig. 13B-4  A, Medial approach incision.

Fig. 13B-4  B, The separation between the soleus and gastrocnemius muscles is first identified in the midcalf. This separation can also be found near the Achilles tendon, but the plane of dissection is less clearly defined. Note the plantaris tendon on the surface of the soleus muscle, indicating that the plane of dissection between the two muscles is correct.
The medial origins of the muscle from the tibia are divided, exposing the flexor digitorum longus, posterior tibial artery and nerve, posterior tibial muscle, and the flexor hallucis longus muscles. Superficially, the soleus is separated from the overlying gastrocnemius and skin, and subcutaneously it is separated more distally to the surface of the Achilles tendon. The muscle is then retracted outward. Distal segmental pedicles from the posterior tibial artery are ligated.

The muscle is divided distally at the level of the malleolus and mobilized from distal to proximal. The amount of muscle division will depend on the degree of the arc of rotation that is required for the reconstruction. Intermuscular septum is noted distally. Proximally, care must be taken to perform division of the muscle at its approximate midpoint or risk not carrying the nutrient vessels. To be safe, some of the lateral muscle can be taken.

Fig. 13B-4  C, A deep muscular perforator is identified passing from the soleus muscle to the undersurface of the gastrocnemius muscle. The soleus muscle is separated from its medial attachment to the tibia starting at the point at which the plantaris tendon crosses the distal muscle. In the area of the Achilles tendon, the soleus muscle must be sharply separated from the gastrocnemius muscle and the Achilles tendon.

Fig. 13B-4  D, The soleus muscle is separated from the Achilles tendon. It is still attached to most of the deep perforating branches from the posterior tibial artery. These deep perforators may be divided if it is necessary to increase the upward excursion of the muscle. If they can be left intact, the blood supply to the muscle flap will be enhanced.
The lateral approach is rarely used; it is more applicable when the hemisoleus is harvested with the fibula. The incision is made and the soleus muscle is identified. The lateral origins of the muscle are divided from the fibula to improve exposure to the peroneal vessels. An areolar plane can be found between the gastrocnemius and soleus muscles and divided with blunt dissection. The soleus is dissected from the peroneal muscles and from the Achilles tendon. The median raphe is located and divided, and the flap is dissected from distal to proximal, ligating segmental vessels as needed for rotation of the flap. The perforating vessels from the peroneal artery can be visualized and spared.

**Fig. 13B-4**  
E, During the dissection of the fibula flap, rather than dissecting away the soleus muscle, the hemisoleus is harvested with the flap (posterior view).  
F, Cross-section of the fibula flap harvested with lateral hemisoleus, all nourished by the peroneal vessels.
FLAP VARIANT
Distally Based Hemisoleus Flap
The distally based hemisoleus flap is based on the minor pedicles, which can be inconsistent and may not completely vascularize the transferred muscle. Because of the unreliability of this flap, based on anatomic variation, defects of the ankle should be reconstructed with another technique of regional or free flap transfer.

Arc to lower third of leg (hemisoleus flap)

Fig. 13B-5
**ARC OF ROTATION**

**Medial Based Hemisoleus Flap**

Although described, the whole-muscle technique is rarely warranted. With division of the minor pedicles and elevation of the distal two thirds of the muscles, the arc of rotation of the hemisoleus will cover the middle third of the tibia. Distal coverage is less reliable, depending on the amount of muscle versus tendon in the flap and the location of the defect.

**Fig. 13B-6**

Arc to middle third of leg (lateral approach) of whole muscle

Arc to middle third of leg (hemisoleus flap)
FLAP TRANSFER
The muscle is easily transposed into the defect either through a direct extension between the donor and recipient sites or through a subcutaneous tunnel.

FLAP INSET
Fascia harvested near the Achilles tendon should be used to secure the flap in place, bearing all the tension of the transfer.

DONOR SITE CLOSURE
Primary closure is easily obtainable, since no skin is harvested from the flap. When a direct transposition has been performed, this area of exposed muscle will be skin grafted. The visible fascia is removed to expose raw muscle to facilitate skin grafting.

CLINICAL APPLICATIONS
This 31-year-old man had a middle third tibial wound after a motor vehicle accident. The exposed bone was covered with a medial hemisoleus flap and skin graft.

Fig. 13B-7  A, The patient had a 12 by 6 cm middle third tibial wound associated with the underlying tibial fracture in the right leg. B, The proximally based medial hemisoleus muscle flap was used to cover the entire middle third tibial wound. C, Completion of the muscle flap inset before skin graft placement. D, Result at 3-month follow-up. (Case courtesy Lee L.Q. Pu, MD, PhD.)
This 35-year-old man had a tibial wound in the junction of the middle and distal thirds of the left leg after a traumatic injury. He had an exposed tibial fracture and small soft tissue defect, which was nicely reconstructed with a local rotational medial hemisoleus flap.

Fig. 13B-8  A, The patient had a 5.5 by 3 cm tibial wound in the junction of the middle and distal thirds of the left leg with an exposed tibial fracture site. B, Completion of the proximally based medial hemisoleus muscle flap before placement of a skin graft. C, Result at 5-month follow-up. (Case courtesy Lee L.Q. Pu, MD, PhD.)
This 41-year-old woman had a tibial wound in the distal third of the right leg close to the medial malleolus from a traumatic injury. There was an exposed tibial fracture site and plate requiring coverage. Normally a free flap would have been required, but because of the presence of distal segmental branches of the posterior tibial artery, a reverse hemisoleus flap was possible.

Fig. 13B-9  A, This woman had a 5.5 by 2.5 cm tibial wound in the distal third of the right leg close to the medial malleolus with an exposed tibial fracture site and plate. B, Completion of the distally based medial hemisoleus muscle flap inset before placement of a skin graft. C, Result at 21-month follow-up. (Case courtesy Lee L.Q. Pu, MD, PhD.)
This 25-year-old man sustained a crush injury to his leg in a motor vehicle accident, fracturing his tibia and fibula without vascular injury.

Fig. 13B-10  A, The patient is seen after stabilization from his other injuries, now 2 weeks after the accident. There is a large upper and middle third of the leg skin defect with exposed devitalized bone and granulation tissue. B, His arteriogram demonstrated intact vessels to the foot. The comminuted fracture of the fibula is seen. C, After aggressive debridement of devitalized tissues, significant defects of the upper and middle thirds of the leg remained. Also, staged bone grafting was desired, so muscle flaps were designed to cover the entire defect with viable muscle. The medial gastrocnemius was harvested for the upper third defect, and the medial hemisoleus was harvested for the middle third defect. Note the scoring of the muscular fascia to extend reach for wound coverage. D, Flaps transposed into the defect, providing total muscle coverage of the wound. The surface of the muscle was skin grafted. E, The patient is seen at 2 weeks postoperatively with uncomplicated healing. (Case supplied by MRZ.)
Pearls and Pitfalls

- The medial hemisoleus flap is a more practical flap than the lateral hemisoleus flap, since it supplies more bulk and has a better arc of rotation for the middle third of the leg.
- Care must be taken when using the laterally based flap to avoid injury to the superficial peroneal nerve and is not recommended.
- Harvest of the entire soleus, both medial and lateral heads, is not recommended, because the bulk actually limits rotation of the muscle, and because the dual blood supply, is not required for “increased” vascularity. Preservation of a hemisoleus also leaves more functional muscle for postoperative leg function.
- In a traumatic injury, when this flap is most indicated, a preoperative arteriogram may be advisable. One should always be prepared for an alternative reconstruction, since the muscle may not be available because of the injury to local tissue.
- Although successful use of distally based soleus muscle has been performed, one should always have a backup plan, because the blood supply to this flap is unreliable, since it depends on smaller inconsistent perforators that often are injured during trauma.

EXPERT COMMENTARY
Lee L.Q. Pu

Indications
Traditionally, the soleus muscle flap has only been used to reconstruct a complex wound in the middle third of the leg. Through better understanding of the vascular supply to the soleus muscle and the development of the medial hemisoleus muscle flap, the usefulness of the medial hemisoleus muscle as a valid option for reconstructing a soft tissue defect in the lower extremity should be revisited. I think, as do others, that the proximally based medial hemisoleus muscle flap can be used to reconstruct a less extensive wound (less than 50 cm² in an adult patient) in the middle third of the leg, in the junction of the middle and distal thirds of the leg, or even in the distal third of the leg. In selected patients, a distally based medial hemisoleus muscle flap can also be used to reconstruct an even more distal third tibial wound of the leg. The proximally based medial hemisoleus muscle flap can also be used in combination with the medial gastrocnemius muscle flap to repair a more extensive proximal tibial wound in the leg if the functional loss of these muscles can be justified.

Advantages and Limitations
I think the medial hemisoleus muscle flap can be a reliable local option and may be able to replace free tissue transfer for soft tissue coverage of a less extensive tibial wound in a middle third, junction of the middle and distal thirds, or distal third of the leg, because the flap can provide a good reconstructive outcome with minimal morbidity and is potentially cost effective. The flap can be performed by most plastic surgeons without microsurgical expertise in a non-university-teaching hospital and can also be considered as a worthwhile alternative to free tissue transfer in soft tissue reconstruction of the lower extremity.

Continued
Scarifying the medial hemisoleus muscle as a local flap may lead to a certain functional deficiency of the leg. However, interpretation of the functional loss in these patients can be difficult, because the history of orthopedic trauma to soft tissue and bone or other factors, such as the fate of fracture healing and the presence of chronic osteomyelitis infection, can definitely influence the results. In general, with at least one head of the gastrocnemius muscle intact, the function of foot plantar flexion can be preserved after transposition of the entire soleus muscle as a flap. Clinically, the functional loss of the leg, if any, after elevation of a medial hemisoleus muscle flap is well tolerated by most patients, although this has not been confirmed by well-controlled studies.

**Anatomic Considerations**

The proximal portion of the soleus muscle receives an independent axial vascular supply to its medial and lateral bellies. The middle or distal portion of the medial half of the soleus muscle receives a segmental vascular supply throughout its length from the posterior tibial vessels. This important anatomic feature makes the medial half of the muscle reliable as a proximally based flap, and this is the anatomic basis for splitting the medial half of the soleus as a medial hemisoleus flap to reconstruct the middle or even distal third of a tibial wound. Injection studies in fresh leg specimens show numerous cross-vascular connections between the two bellies of the muscle, and there is a reversed blood flow from the distal lateral half of the muscle to the medial half of the muscle if the medial hemisoleus muscle is elevated as a “distally” based flap. Therefore the medial hemisoleus muscle flap can be elevated based both proximally and distally, depending on the location of the soft tissue reconstruction required.

![Fig. 13B-11](image)

**Fig. 13B-11**  
**A**, Flap dissection and blood supply to the proximally based medial hemisoleus muscle flap. The flap is based proximally and receives blood supply primarily from the posterior tibial vessels. The flap also receives additional blood supply from one or two distal perforators of the posterior tibial vessels to its distal portion. **B**, Flap dissection and blood supply to the distally based medial hemisoleus muscle flap. The flap is based distally and receives blood supply primarily from the most distalmost two or three perforators of the posterior tibial vessels.
Personal Experience and Insights

Although the use of a medial hemisoleus muscle flap to reconstruct a wound in the distal third of the leg still remains controversial, the flap can be used successfully to reconstruct a less extensive wound (less than 50 cm²) in the distal third of the leg. Based on my experience, the proximally based medial hemisoleus muscle flap can be used for a relatively proximal tibial wound in the junction of the middle and distal thirds or in the distal third of the leg. The flap is fairly reliable, and the procedure can often be performed within 2 hours. In addition, the flap can provide just enough muscle bulk for soft tissue coverage of the tibial wound, and thus reconstructive outcomes are usually quite good.

The distally based flap can be used for a less extensive distal tibial wound (often close to the medial malleolus) in the distal third of the leg. The flap can be reliable in most healthy, compliant patients. However, the flap should not be used in patients with significant peripheral vascular disease because of the potential poor inflow of the posterior tibial artery, or in those with significant diabetes because of the potential small vessel disease in those perforators. The initial venous congestion may also become a problem in certain patients, such as smokers or those with an inability for leg elevation during the postoperative period.

Recommendations

Planning

The availability and usefulness of the soleus muscle can be determined by direct surgical exploration or preoperative MRI before a proximally or distally based medial hemisoleus flap is planned. In general, the first large perforator (usually the proximalmost one) from the posterior tibial vessels to the distal medial soleus muscle serves as a pivot point in the flap turnover; the level of this perforator will determine how far the flap can reach to the distal leg. Therefore a preoperative angiogram can be part of the workup when planning a distally based medial hemisoleus flap.

Technique

For a proximally based medial hemisoleus flap, its insertion is divided distally at the level close to the Achilles tendon, depending on the length of the flap rotation required. The medial half of the muscle is split longitudinally along with a raphe between the bellies of the soleus muscle. In a standard flap dissection, the major perforators are divided from the posterior tibial vessels to the medial hemisoleus muscle and the distal two thirds of the muscle are elevated so that the flap can be based on the dominant pedicles proximally.

Fig. 13B-12 An intraoperative view shows an adjacent perforator (indicated by forceps) from the posterior tibial vessels to the medial hemisoleus muscle flap. Preservation of this perforator may be critical to ensure an adequate blood supply to the distal portion of the proximally based flap.

Continued
In contrast, the medial hemisoleus muscle flap is elevated while preserving as many minor pedicles as possible to the flap in the middle or even distal third of the leg, still allowing adequate arc rotation of the flap to cover a wound in the middle third of the leg.

To cover a wound in the junction of the middle and distal thirds of the leg, the flap is elevated only to the level just above the junction between the middle and distal thirds of the leg so that an adjacent perforator from the posterior tibial vessels to the flap can be preserved while allowing adequate arc of the flap rotation. To cover a wound in the distal third of the leg, the flap is elevated only to the level just below the junction between the middle and distal thirds of the leg with emphasis on the preservation of as many major perforators to the flap as possible even in the distal third of the leg while allowing adequate arc of flap rotation. Compared with the standard medial hemisoleus muscle flap used to reconstruct a wound in the middle third of the leg, the longitudinal splitting of the soleus muscle can be extended more laterally so that the distal portion of the flap can be made big enough to adequately cover a wound in the distal third of the leg. During the flap dissection, only the muscular portion of the soleus muscle is used as the flap, while the tendinous portion of the soleus is left intact. The spared tendon can be approximated to the remaining lateral half of the soleus muscle.

For a distally based medial hemisoleus muscle flap, the medial half of the muscle is divided and then split longitudinally, along with a raphe between the heads of the soleus muscle to the level of the junction of the middle and distal third of the muscle. Unlike the flap dissection recommended by others, where the major perforators from the posterior tibial vessels to the medial hemisoleus muscle in the distal middle third of the tibia are divided, attention is made to preserve as many major perforators from the posterior tibial vessels to the flap as possible even in the distal middle third of the tibia while allowing adequate arc of the flap turnover to cover a wound in the distal third of the leg. In addition, the first large perforator from the posterior tibial vessels can be dissected further as one would do during a perforator flap dissection. This maneuver may provide a longer arc of the flap turnover because the level of this particular perforator would serve as a pivot point for flap turnover and be able to determine how far this flap can reach to the distal leg. With this technique, the flap can often reach the proximal border of the medial malleolus after elevation.

Fig. 13B-13  An intraoperative view shows the first large perforator (indicated by forceps) from the posterior tibial vessels to the distally based medial hemisoleus muscle flap. This perforator serves as a pivot point for flap turnover and preserving it may be critical to ensure an adequate blood supply to the distal portion of the distally based flap.
Postoperative Care
The postoperative care regimen in my practice includes bed rest with leg elevation to reduce edema and placement of a warming unit around the leg to maintain a warm temperature for the first few days after flap surgery.

Complications
Like any other pedicled flap, distal flap necrosis may occur, but total flap loss should not happen if the medial hemisoleus muscle flap is performed properly. Fortunately, the distal flap necrosis is usually insignificant and can be managed with debridement. The flap can then be readvanced adequately to cover the wound, and the final outcome can still be good. Further advancement of the flap is possible by dividing the proximalmost perforator, which has served as a pivot point, since the flap has been “delayed” after initial flap elevation. In general, distal flap necrosis occurs infrequently if the flap is proximally based but occurs in about 20% of patients if the flap is distally based.

Take-Away Messages
Before dissecting the medial hemisoleus muscle flap, the surgeon should make certain that the soleus muscle has not been traumatized from the previous injury. When performing a proximally based flap, one should preserve any perforators from the posterior tibial vessels to the distal medial half of the soleus muscle just at or above the level of a tibial wound while allowing adequate arc of flap rotation to cover a wound in the distal third of the leg. The modifications of surgical techniques emphasize the preservation of an adequate blood supply to the distal portion of the medial hemisoleus muscle flap after the flap is elevated. These techniques would maximize the reliability of the medial hemisoleus muscle flap and expand its role in reconstruction of a wound in the distal third of the leg.

With a preoperative angiogram, major perforators in the lower third of the leg can be identified when planning a distally based medial hemisoleus flap. The proximalmost perforators from the posterior tibial vessels to the medial half of the distal soleus muscle within the upper distal third of the leg should be preserved while allowing adequate flap turnover to cover a tibial wound in the distal third of the leg. This perforator will serve as a pivot point for flap turnover, and the level of the perforator will determine how far this flap can reach. The modified surgical techniques in flap dissection indeed emphasize preservation of an adequate blood supply to the distal portion of the distally based flap and maximize reliability of the medial hemisoleus muscle flap even when it is based distally.

However, free tissue transfer should still be considered for a larger soft tissue wound in the middle or distal third of the leg, or for a less extensive wound when either the soleus muscle or the perforators from the posterior tibial vessels are traumatized.
Bibliography With Key Annotations

Anatomic/Experimental Studies

The authors presented principles of muscle flap transposition, emphasizing the vascular anatomy of muscles. Latex injection techniques were used to study the vascular anatomy of leg muscles, including the gastrocnemius, soleus, peroneus longus, and peroneus brevis.


In this landmark article, the authors reviewed the application of muscle flaps to date and describe the anatomy and arc of rotation of the medial head of the gastrocnemius, lateral head of the gastrocnemius, soleus, flexor digitorum longus, extensor hallucis longus, and abductor hallucis. They also described the vascular supply and point of rotation of each muscle. They further demonstrated the usefulness of muscle flaps for various reconstructive purposes, including repair of poorly vascularized defects of the lower leg, padding of bony prominences, repair of the thoracic wall, protection of large vessels, filling the empty orbit, filling the retropubic cavity, controlling urinary incontinence, aiding in wound closure, contour restoration, and closure of vesicovaginal fistulas. The soleus was used in three patients with tibial fractures, one of whom had osteomyelitis. The authors reported a successful reconstruction in all patients.

Clinical Series

The authors presented an anatomic description and clinical demonstration of a compound myocutaneous innervated free flap for functional transfer that includes fibular bone, the lateral half of the soleus, and overlying skin. In this case report the authors reconstructed a forearm defect consisting of missing radial bone, soft tissues, and extensor muscles. Excellent wrist and finger extension was demonstrated at 4-year follow-up.


The technique of elevation of muscles for transposition for coverage of the tibia was presented. Based on the location of the defect, the gastrocnemius was described for upper third, soleus for middle third, and flexor digitorum longus for lower third defects.


The authors introduced the concept of segmental muscle transposition, allowing use of muscle as a flap for coverage while maintaining the continuity of the muscle with its origin and insertion. This technique is pertinent to lower leg reconstruction when leg function may be diminished following muscle injury. Techniques for function preservation and the anatomic basis were presented for the soleus, flexor digitorum longus, and tibialis anterior.

Flap Modifications

Traditionally, cross-leg flaps and microsurgical flaps have been used to reconstruct defects of the distal third of the leg. In the authors’ experience, the soleus muscle has also provided suitable tissue for coverage of these lesions in a notable number of cases. During a 2-year period, the authors treated 28 patients who required flap coverage of defects of the lower third of the leg. In this group, the soleus muscle was used successfully in 8 patients. All of these procedures resulted in healed wounds. The remaining patients underwent reconstruction with microsurgical flaps, fasciocutaneous local flaps, and
a gastrocnemius muscle flap. Their experience demonstrated that the soleus muscle is a valuable tool and should be included in the treatment algorithm for reconstructing lesions of the distal third of the lower extremity.


Based on anatomic studies of 10 fresh cadavers, the authors described a distally based split soleus flap that proved successful in eight procedures in seven patients. Anatomic studies included dissections and barium injection studies. The authors advocated splitting the muscle along an intramuscular septum rather than cutting to preserve intramuscular vessels. Proximal pedicles in the vicinity of the tibial origin are divided. This splitting technique preserves the intramuscular vasculature, thus enhancing flap safety.


The authors proposed a refinement of the previously described distally based soleus muscle flap. The essential features of the flap are mobilization of the tibial origin, splitting the muscle longitudinally, partially along a distinct anatomic plane, and preservation of the anatomic continuity of the muscle. They suggested that improved blood supply to this flap derives from the intact major lateral proximal pedicles via the intact lateral portion into the flap. They also stated that minimal damage to intramuscular vasculature integrity contributes to the improved circulation. The flap was designed and studied using 10 fresh cadaver leg dissections. Angiographic studies proved adequate blood supply to the flap. The flap was tested 8 times on 7 patients with favorable results.


The use of local transposition muscle flaps for coverage of the lower extremity has been overshadowed in recent years by the development of microsurgical techniques for tissue transfer. There are still definite indications for local muscle flaps in reconstruction of the lower extremity. An outline of criteria of selectivity as it applies to specific wounds and practical pitfalls of their use was presented.


Although it is recognized as the muscle flap of choice for middle-third defects of the lower limb, the capability for even more distal transposition of the soleus muscle remains controversial. Such reach depends directly on the site of insertion of the muscle and previously has not been assessed convincingly without surgical intervention. MRI scanning may be a noninvasive alternative for determining the distal extent of the myotendinous junction of the soleus muscle. In our last four patients, preoperative MRI scans were obtained before an elective soleus muscle transfer. The distance from the ankle joint to the distalmost site of the soleus insertion was measured on the MRI scan and compared with the actual intraoperative measurement, which had a significant correlation. A retrospective review of 42 other sagittal ankle MRI scans predicted the mean of this distance to be 1.92 ± 1.23 cm (range −0.4 to 4.5 cm), compared with gross anatomic dissections in 30 unrelated fresh cadavers, where this was 4.06 ± 3.11 cm (range −0.7 to 12.5 cm). These additional data are pertinent because they reinforce recognition of the great variation in soleus anatomy, which would limit clinical applications for the distal third of the leg only for those individuals with very distal insertions. The MRI scan can reliably identify the soleus muscle and provides a nonoperative method for evaluation of potential feasibility for its use as a local muscle flap for distal lower extremity defects.


There is only limited objective information about functional donor site morbidity after harvest of one head of the triceps surae muscles to cover a severe soft tissue defect of the leg. The purpose of this study was to investigate whether a functional deficit is present during level and uphill walking after such a procedure. Five subjects who had completely recovered from the initial injury were studied with use of comprehensive gait analysis during free level, fast level, and uphill walking on a ramp at a 10-degree
inclination. Gait analysis revealed no relevant donor site morbidity affecting level gait at a free walking speed (mean 1.27 m/sec; range, 1.18 to 1.40 m/sec). When the subjects walked at a higher velocity (mean 1.89 m/sec; range, 1.58 to 2.43 m/sec), an asymmetry of the ground-reaction forces was seen. The second vertical peak force during push-off was reduced by a mean of 7.3% (range 0.94% to 12.24%), and the impulse in the direction of progression was reduced by a mean of 8.7% (range 0.13% to 17.87%) on the affected side (p = 0.04). During uphill walking, a compensatory strategy to reduce the demand on the posterior calf muscles was seen in all subjects; that is, they shortened the length of the step on the contralateral side by a mean of 3.9 cm (range 2.2 to 6.2 cm), which corresponded to a mean side-to-side difference of 5.6% (range 2.18% to 6.18%) (p = 0.04). A calcaneal motion pattern, denoted as increased ankle dorsiflexion, was seen in three of the five subjects during uphill walking as a sign of decreased function of the posterior calf muscles. Two of them (both with a soleus flap) also had a calcaneal pattern during fast gait. The authors concluded from this study that the functional donor site morbidity after harvest of one head of the triceps surae muscles is mild in subjects who have had a complete recovery from their initial injury. Normal level gait is possible. However, deficits are seen in more demanding tasks, such as fast walking or uphill walking.


The role of a local flap for soft tissue reconstruction of a tibial wound in the distal third of the leg has not been clearly defined in the literature. Since the initial experience was published, the author has successfully used the medial hemisoleus muscle flap in more patients who had a relatively less extensive tibial wound in the distal third of the leg. In this follow-up report, further refinements in the flap dissection and results from long-term experience on the outcome of fracture healing and ambulation are reported. The indications for the medial hemisoleus muscle flap are also clearly outlined.


Although the medial hemisoleus muscle has been considered a local reconstructive option for soft tissue reconstruction of the middle-third tibial wound, its reliability and usefulness has been debated among plastic surgeons. This study reported one surgeon's experience with medial hemisoleus muscle flaps and shows their application or soft tissue reconstruction of middle-third tibial wounds. Over the past 2 years, 10 patients underwent soft tissue reconstruction of a middle-third tibial wound with medial hemisoleus muscle flap and skin graft. The flap was elevated with emphasis on the preservation of as many perforators to the flap as possible while allowing adequate arch rotation of the flap to cover the exposed tibia and/or hardware. All patients were followed for up to 2 years. There was no total flap loss, and limb salvage was achieved in every patient in this series. Only two patients with peripheral vascular disease developed small partial but insignificant distal flap necrosis that was treated with debridement and flap advancement. The tibial wounds of all patients subsequently healed with excellent cosmetic outcome during follow-up. The results from this study indicate that the medial hemisoleus muscle flap is reliable for soft tissue reconstruction of a middle-third tibial wound. Meticulous flap elevation with the preservation of perforators to the flap is the key for such success.


The usefulness of a reversed hemisoleus muscle flap as a local reconstructive option for soft tissue coverage of an open tibial wound in the lower third of the leg has never been acknowledged. Eight patients underwent soft tissue reconstruction of an open tibial wound (3 by 3 to 10 by 6 cm) in the lower third of the leg with the reversed medial hemisoleus muscle flap modified by the author. The flap was dissected with attention to preserving several critical perforators from the posterior tibial vessels to the flap as possible while allowing adequate turnover of the flap to cover the exposed tibia or hardware. There was no total flap loss, and limb salvage was achieved in all patients. Two patients
developed insignificant distal flap necrosis; they were treated subsequently with debridement and flap readvancement. All patients had reliable healing of their tibial wounds, with good reconstructive and cosmetic outcomes of the flap reconstructions during follow-up. Therefore the author stated that the reversed medial hemisoleus muscle flap can be a good choice for soft tissue coverage of a sizable open tibial wound in the lower third of the leg and may be used successfully to replace free tissue transfer in selected patients.


The proper soft tissue management for an extensive mid-tibial wound of the leg with a less aggressive surgical approach has rarely been discussed in the literature and the reliability and the usefulness of such an approach to this challenging clinical problem remains uncertain. In this series, four patients with an extensive midtibial wound (12 by 3 cm to 22 by 6 cm) of the leg underwent the combined medial gastrocnemius and medial hemisoleus muscle flaps for soft tissue reconstruction. Both muscle flaps were elevated with emphasis on the preservation of the critical perforators from the posterior tibial vessels to the medial hemisoleus muscle flap as possible and on the possible preservation of foot planter flexion by reconstruction of the proximal Achilles tendon to minimize functional loss. All patients except one had primary healing of their tibial wounds. One patient developed insignificant distal flap necrosis of the medial soleus flap and was treated with debridement and flap readvancement. Three patients with tibial fracture also had evidenced healing of their tibial fractures. Limb salvage was achieved in all four patients during follow-up. Thus the combined medial gastrocnemius and medial hemisoleus muscle flaps can be a valid option for soft tissue coverage of an extensive mid-tibial wound of the leg when both local muscle flaps are not traumatized. Such an approach offers a relatively simple but more cost-effective way to manage this complex clinical problem and should be revisited by reconstructive surgeons.

Pu LL. Soft tissue coverage of an open tibial wound in the junction of the middle and distal thirds of the leg with the medial hemisoleus muscle flap. Ann Plast Surg 56:639, 2006.

A relatively simple but reliable option for soft tissue coverage of a less extensive tibial wound in the junction of the middle and distal thirds of the leg has never been determined. In this series, the author reported his clinical experience using the medial hemisoleus muscle flap as a local reconstructive option for management of this unique clinical problem. Fourteen patients underwent soft tissue reconstruction of an open tibial wound (4 by 3 cm to 10 by 5 cm) in the junction of the middle and distal thirds of the leg with the proximally based medial hemisoleus muscle flap. Only the medial half of the soleus muscle was elevated, with attention to preserving critical perforators from the posterior tibial vessels to the flap while allowing adequate arc of flap rotation to cover the exposed fracture site and hardware. All patients were followed for up to 2 years. One patient developed insignificant distal flap necrosis and was treated with debridement and flap readvancement. All patients had primary healing of their wounds, reliable soft tissue coverage, evidenced fracture healing, and good cosmetic outcome during follow-up. Therefore the medial hemisoleus muscle flap described can be a reliable local option for soft tissue coverage of a less extensive tibial wound in the junction of the middle and distal thirds of the leg with good outcome and minimal morbidity.


A total of 33 patients, each with an open tibial wound in the distal third of the leg, underwent a skin grafted muscle flap reconstruction according to the new treatment algorithm developed by the author. When the size of the soft tissue defect was less than 50 cm, a pedicled medial hemisoleus muscle flap was used for the soft tissue coverage (n = 20). If the soleus muscle was traumatized, a small free muscle flap (gracilis) was then used (n = 3). When the size of the soft tissue defect was greater than 50 cm, a larger free muscle flap (rectus abdominis or latissimus dorsi) was selected (n = 10). All patients were followed for up to 4 years. Three patients with a medial hemisoleus muscle flap developed insignificant distal flap necrosis and were treated subsequently with debridement and
flap advancement. Five patients with a free muscle flap required an additional operation, and two patients had a subsequent debulking procedure of the flap for contour improvement of the leg. Reliable soft tissue coverage with a well-healed tibial wound, evident fracture healing, and good contour of the leg were achieved in all patients during follow-up. Following this new treatment algorithm, a selected option for an open tibial wound in the distal third of the leg can provide reliable soft tissue coverage for different sizes of open tibial wounds and may offer a more cost-effective approach for managing such a complex clinical problem.


Soft tissue defects of the lower limb are a formidable challenge to the plastic surgeon, but a soleus muscle flap often provides the solution. Various types of soleus muscle flap have been described, based mainly on the vascular supply. The arterial blood supply of the soleus muscle was studied in 50 cadaveric lower limbs. The blood vessels and their branches to the muscle were dissected. The distance of the origin of the perforators was measured from fixed bony landmarks. Branches of the popliteal artery trunk, the posterior tibial artery, and the peroneal artery supplied the soleus muscle. The number of branches to the soleus muscle from these main arteries were analyzed. The medial part of the muscle was supplied throughout its length by perforators arising from the posterior tibial artery. This constant feature makes the medial part of the muscle reliable as a proximally or distally based flap. The average distances of the lower perforators arising from the posterior tibial artery were 6.5 cm, 11.6 cm, and 16.8 cm from the medial malleolus. The branches of the peroneal artery were mostly distributed in the upper half of the muscle. These large pedicles allow a composite transfer of the soleus muscle with the fibula. Lower perforators were demonstrated to arise from the peroneal artery in 60% of the limbs, but the scarcity of perforators in this region limits the clinical usefulness of an inferiorly based lateral hemisoleus flap. The study demonstrated the distribution of arteries entering the soleus muscle and how the information may be used in the design of soleus muscle flaps. The average numbers of the perforators arising from the vessels and their distribution were highlighted.


A total of 36 cadaver and fresh amputation specimens were studied by dissection. Two vascular patterns were identified: a segmental posterior tibial artery (type 1) and a proximally dominant posterior tibial artery (type 2). Type 1 was seen in 77.8% of cases and type 2 in 22.2%. Injection studies in five fresh specimens demonstrated numerous cross-connections between the two halves of the muscle. A distally based hemisoleus flap should not be performed when a type 2 vascular pattern is encountered. Also, vascular cross-connections between the two halves of the soleus muscle should be preserved when possible.


The reliability of the distally based pedicled hemisoleus flap for coverage of relatively small medial distal third leg wounds has been continuously debated among reconstructive surgeons. Whereas some investigators report that the distally based hemisoleus can be elevated safely, other authors argue that the flap’s retrograde blood supply is problematic. The authors stated that application of angiosome principles may help surgeons to better design the distally based hemisoleus flap so that outcomes are optimized. Seventeen patients received a distally based hemisoleus flap for coverage of a small distal third leg wound. Flaps were designed to capture one full angiosome and only a portion of the adjacent angiosome. Reliable soft tissue coverage and wound healing were achieved in all patients. A mean operative time of 130 minutes reflected the relative technical ease and efficiency of the surgery. Only one patient developed distal tip flap necrosis, which did not compromise soft tissue coverage and ultimately resulted in a healed wound and fracture. The distally based hemisoleus flap is an efficacious method of treating small distal third medial tibial wounds. Flap design based on vascular perforator angiosome principles may help surgeons improve the reliability of this flap.

This study was conducted to analyze the cost and outcome of free tissue transfers versus local muscle flaps for reconstruction of limited soft tissue defects associated with tibial fractures in the distal third of the leg. Twelve adult patients who underwent either free (n = 6) or local muscle (n = 6) flap reconstruction were retrospectively reviewed. Total operative time for local muscle flap reconstruction was 215 ± 47 minutes compared with 450 ± 90 minutes (p < 0.0002) for free muscle transfer. Median length of hospital stay after reconstruction was 7 days for local muscle flap compared with 9 days for free muscle transfer. The total cost of the local muscle flap procedure was $11,729 ± $4460 compared with $19,989 ± $3295 (p < 0.0004) for free flap reconstruction. Five of six patients in each group had excellent soft tissue contours. Fracture healing was evident in all patients of each group. Thus a local muscle flap for reconstruction of a limited distal tibial wound appears to be more cost effective than free tissue transfer because of equivocal outcomes achieved, but at approximately half the cost.


This paper reported an anatomic study of the soleus muscle and clinical applications of the findings derived from the study. Soleus neurovascular anatomy was studied in 86 limbs by dissection and specimen angiography. A consistently present bipenniform muscle morphology was found, with medial and lateral subunits that had independent distal neurovascular supplies. This anatomic feature allows surgically splitting the muscle for transfer of half the muscle as a flap (hemisoleus muscle flaps). A series of 33 patients using both medial and lateral hemisoleus flaps in both proximally and distally based transfer was analyzed, and illustrative examples were presented. The primary value of this technique is the ability to retain half the innervated soleus muscle in situ to preserve foot plantar flexion power in ambulatory patients. In addition, hemisoleus flaps have an extended arc of rotation compared with that of conventional soleus muscle flaps.


A method for covering soft tissue defects overlying the distal tibia with a proximally based soleus muscle flap was described. The flap can be used to cover a portion of the distal tibia by extending the distal reach of the soleus muscle. The muscle is extended by several relaxing incisions in the epimysium. This simple procedure enables the soleus muscle to be advanced distally, extending its application for coverage of the distal lower leg. The method has been used successfully clinically, eliminating the need for more time-consuming or difficult procedures.
ANATOMIC LANDMARKS

Landmarks
Flap is located between the popliteal fossa and the midportion of the leg centered over the midline raphe between the medial and lateral heads of the gastrocnemius muscle.

Size
10 × 12 cm.

Composition
Fasciocutaneous.

Dominant Pedicle
Sural artery perforator.

Minor Pedicles
Fasciocutaneous perforators from the peroneal artery; fasciocutaneous perforators from the posterior tibial artery; neurocutaneous perforators from the vasa nervorum of the sural nerve; venocutaneous perforators from the vasa vasorum of the lesser saphenous vein.

Nerve Supply
Medial Sensory: Medial sural cutaneous nerve (S1-S2).
Section 13C

LEG
Sural Artery Flap

CLINICAL APPLICATIONS

Regional Use
- Knee
- Popliteal fossa
- Upper third of leg
- Ankle
- Heel
- Foot reconstruction
Fig. 13C-1  The arterial basis for the sural flap is a branch arising either from the popliteal artery or from the lateral sural artery. From its origin, the artery usually follows the course of the lateral sural cutaneous nerve, reaching the overlying fascia approximately 5 cm inferior to the popliteal crease. The artery and nerve continue distally in a subfascial course for a variable distance. Both suprafascial and subfascial plexuses are supplied by these class B fasciocutaneous vessels. The lesser saphenous vein courses in a subcutaneous plane between the two heads of the gastrocnemius muscle. Paired venae comitantes accompany the fasciocutaneous artery; these veins are preferentially used to establish venous drainage for the transplanted flap. The lesser saphenous vein is usually not employed. The lateral sural cutaneous nerve arises in the popliteal fossa from the common peroneal nerve. After giving rise to a communicating nerve, it usually penetrates the deep fascia 5 to 10 cm distal to the popliteal crease supplying the fascia and skin of the lateral two thirds of the leg.

**Dominant pedicles:** Sural artery perforator

**Minor pedicles:** Fasciocutaneous perforators from peroneal artery; fasciocutaneous perforators from posterior tibial artery; neurocutaneous perforators from vasa nervorum of sural nerve
ANATOMY

Landmarks This flap occupies the posterior leg between the popliteal fossa and the midportion of the leg and is centered over the midline raphe between the medial and lateral heads of the gastrocnemius muscle.

Composition Fasciocutaneous.

Size 10 × 12 cm; larger flaps have been reported in the literature. Flaps greater than 6 cm wide require skin grafting for donor site closure.

Arterial Anatomy

Dominant Pedicle *Sural artery perforator*

**REGIONAL SOURCE** Popliteal artery.

**LENGTH** 3 cm.

**DIAMETER** 1.4 mm.

**LOCATION** This pedicle descends from the popliteal fossa between the heads of the gastrocnemius muscle and deep fascial layer and courses inferiorly, superficial to the gastrocnemius muscle.

Minor Pedicle *Perforators from the peroneal artery*

**REGIONAL SOURCE** Peroneal artery.

**LENGTH** 1 cm.

**DIAMETER** 1 mm.

**LOCATION** Distal third of the leg.

Minor Pedicle *Perforators from the posterior tibial artery*

**REGIONAL SOURCE** Posterior tibial artery.

**LENGTH** 1 cm.

**DIAMETER** 1 mm.

**LOCATION** Distal third of the leg.

Minor Pedicle *Neurocutaneous perforators from the vasa nervorum of the sural nerve*

**REGIONAL SOURCE** Sural artery.

**LENGTH** 1 cm.

**DIAMETER** Greater than 1 mm.

**LOCATION** The rich anastomotic vasa nervorum of the sural nerve gives off neurocutaneous perforating vessels to the skin and the fascia overlying it.

Venous Anatomy

Venae comitantes accompany all perforating vessels to the flap in the reverse flow flap. When a skin island is kept intact, venous egress also occurs through the subdermal plexus.

Nerve Supply

**Sensory** Medial sural cutaneous nerve (S1-S2), which is a branch of the tibial nerve within the popliteal fossa. This courses with the lesser saphenous vein and cutaneous artery.
VASCULAR ANATOMY OF THE SURAL ARTERY FLAP

Fig. 13C-2

Dominant pedicle: Direct cutaneous artery and lesser saphenous vein (D)
Minor pedicle: Myocutaneous perforating artery (m)
n, Sural nerve; v, lesser saphenous vein
**FLAP HARVEST**

**Design and Markings**

The skin paddle design will run from the popliteal fossa to the midportion of the leg, its width depending on the reconstructive need.

*Fig. 13C-3*  
A, Design for anterograde flap. B, The design of the distally based superficial sural artery flap on the posterior aspect of the leg. The skin island can be raised anywhere in the lower two thirds of the leg. The pivot point of the pedicle must be at least 5 cm above the lateral malleolus to keep the anastomoses with the peroneal artery.

**Patient Positioning**

The patient is placed in the prone position.
GUIDE TO FLAP DISSECTION
For the anterograde flap, a Doppler probe is used to determine the location of the course of the pedicle within the flap. Flap borders are then incised through skin and deep fascia. Flap elevation begins distally. The lesser saphenous vein and sural nerves are encountered and divided, and both structures are included with the flap. As the flap is elevated proximally toward the popliteal fossa, dissection is performed in a subfascial plane between the deep fascia and the underlying medial lateral gastrocnemius muscles. Careful dissection proceeds as the popliteal fossa is approached and the entrance of the medial superficial sural artery into the deep fascia is visualized. Elevation proceeds until an acceptable arc of rotation is achieved to cover the defect.

FLAP VARIANTS
- Reverse sural flap
- Adipofascial flap
- Delayed flap
- Supercharged flap
**Reverse Sural Flap**
The most common usage of the flap is for distal-third defects of the leg. Here the reverse sural flap permits soft tissue reconstruction without the need for microsurgery. It does not sacrifice any of the three major arteries to the distal extremity. The distally based reverse sural artery flap is based on the fasciocutaneous blood supply of the distal posterior lateral leg. The structures supplying the flap include the sural nerve superficially, the sural arteries, and the lesser saphenous vein. These structures are all divided proximally while the flap is elevated.

![Image of Reverse Sural Flap](image_url)

**Fig. 13C-5**  
A, Skin island raised and sural pedicle identified. B, The skin island is raised with the deep fascia. The subcutaneous fascial pedicle is elevated, keeping a width of 2 cm to include the sural nerve and the short saphenous vein. C, Flap transposed and donor site skin grafted.
The classically described axial arterial flow to the flap is provided by septocutaneous perforators arising from the peroneal artery, of which there are typically three to six. These perforators pass between the fibula and the flexor hallucis longus proximally in between the soleus and the peroneus longus distally and directly supply the superficial sural arterial system. These perforators are located within 7 cm proximal to the lateral malleolus. Contributions from the lateral malleolar artery and lateral calcaneal artery are also likely present. This flap is also supplied by septocutaneous perforators arising from the posterior tibial artery. These perforators lie within 10 cm of the medial malleolus and pass between the tibia and the soleus proximally and in between the flexor digitorum longus and soleus more distally. The sural nerve is identified proximally early in the dissection and is divided. It is thought that the rich vasa nervorum that accompany the sural nerve are important to the vascularity of the flap; therefore the connections with the overlying fascia are preserved. Venous drainage of the flap is likely not based on the lesser saphenous vein because of the valves in the system. However, collateral veins parallel to the saphenous vein allow blood to run, bypassing this valvular system and providing retrograde flow. Venae comitantes that parallel the peroneal and posterior tibial vessels also provide drainage of the flap. When the distal skin is kept intact, the superficial dermal plexus supplies an additional source for venous egress. When designing the flap, the surgeon first determines the pivot point distally. This is usually within 5 to 7 cm proximal to the lateral malleolus and can be confirmed using a handheld Doppler to ensure occlusion of perforators.

The flap is elevated under tourniquet control, and dissection proceeds from proximal to distal. The flap is initially incised through fascia to the gastrocnemius muscle. The sural nerve, the lesser saphenous vein and the superficial sural artery are transected and ligated in the course of this incision. There is some controversy as to the minimum width of the pedicle. Some authors prefer it to be as wide as the widest portion of the skin island down to the pivot point; others contend that as long as the medial superficial sural artery and the lesser saphenous vein are included, there is no minimum width for the pedicle.

**Adipofascial Flap**

When skin is not required, but soft tissue fill is necessary, the sural flap can be harvested, leaving skin in place, undermining in the subcutaneous plane, carrying only the adipose tissue and fascia for fill. Dissection is similar to that described previously.

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**Fig. 13C-6** The fascial flap supplied by the superficial sural vessels. The deep fascia without a skin island can be elevated safely.
Delayed Flap
One of the weaknesses of the sural flap, especially the reverse variant, is venous congestion, which may lead to partial flap loss. One solution is to perform the flap in stages and create a delayed flap. When creating a delay of the sural flap, the proximalmost portion of the flap is maintained with the skin bridge. The remainder of the flap is dissected as previously described, including complete elevation of the flap below the fascia. This means that the skin island is being supplied by the vessels that normally supply the flap, but a bridge of the skin has been maintained to allow venous egress. The sural artery, sural nerve, and lesser saphenous vein should be divided at the initial elevation, if possible. This allows axialization of vessels within the flap over time, which allows it to become more reliant on the retrograde vessels. At 7 to 10 days, this area of connection can be divided in the office, and the flap can be rotated into position at 2 weeks.

Supercharged Flap
Another solution to the venous egress problem is to include the lesser saphenous vein and some extension of it in the flap. Once the flap is rotated into position, a venous anastomosis can be performed between the lesser saphenous vein and any recipient vein in the area. Another simple solution using this lesser saphenous vein is to cannulate the vein and to drain this at the bedside at intervals. This usually requires only 48 hours of such draining before flap congestion is no longer an issue.
ARC OF ROTATION

Anterograde Flap
The anterograde flap rotates to the defects of the popliteal fossa and upper third of the leg.

Reverse Flap
The reverse flap reaches the ankle, heel, and foot.
**FLAP TRANSFER**

**Standard Flap**
The standard flap is often rotated through a direct incision uniting the donor sites and recipient sites. This allows minimalization of the dog-ear created by its rotation.

**Reverse Flap**
The flap is transposed directly to the defect. One must decide whether a direct connection in the subcutaneous plane will allow transfer and closure, or whether the pedicle will not be buried but skin grafted to prevent compression.

**FLAP INSET**

**Standard Flap**
Inset is performed without tension and without compromise to the vascular pedicle.

**Reverse Flap**
Care is taken at inset not to cause any unnecessary compression of the pedicle or kinking. Skin grafting of the pedicle is often necessary around the area of the ankle and potentially would require a secondary revision.

**DONOR SITE CLOSURE**
Skin grafting is normally needed for the sural donor site. The use of tissue expansion or a wound closure device has been described to eliminate the need for a skin graft, either delayed or immediate.
CLINICAL APPLICATIONS
This 61-year-old man had a history of cardiomyopathy and cardiac transplantation. He developed a myoepithelioma on his foot. The lesion was biopsied, excised, and reexcised. A delayed split-thickness skin graft to the area failed, and the decision was made to perform a fasciocutaneous sural flap.

Fig. 13C-10  A, This defect developed after tumor excision and a failed skin graft. B, The flap was designed with a distal tail-like extension. C, The flap was completely elevated, maintaining a wide base 5 cm above the malleolus.
The flap was rotated into the defect.

E and F, The flap was inset with a small-lumen angiocatheter placed in the lesser saphenous vein.

G, Before skin grafting the donor site, purse-string sutures were placed to decrease its size.

H, The healed flap is shown 4 weeks postoperatively. (Case courtesy Detlev Erdmann, MD.)
This 69-year-old man presented with bilateral heel ulcers and calcaneus exposed under the necrotic eschar. The patient’s medical history included lower extremity claudication, hepatitis A, B, and C, and ongoing tobacco use. The preoperative workup revealed significant peripheral vascular disease, with lesions in the bilateral superficial femoral arteries that were amenable to percutaneous angioplasty and stenting. After undergoing debridement of all necrotic soft tissue and bone and a course of wound-VAC therapy, the patient was taken to the operating room for bilateral reverse sural island flaps to cover his calcaneal wounds. Split-thickness skin grafts were used to cover the donor sites. The patient was discharged on postoperative day 6. The flaps healed without complications.

Fig. 13C-11  
A, Preoperative appearance of bilateral heel ulcers. B, The right heel after debridement of bone and soft tissues, now with calcaneus exposed in the wound. C, Skin incisions and proximal flap dissection. D, After rotating the flap into the defect site. E, The flap was sutured into the defect site, and a small skin graft was placed over the fascial pedicle. F, The healing right ankle flap and G, left ankle flap are seen 3 weeks postoperatively. (Case courtesy Detlev Erdmann, MD.)
Pearls and Pitfalls

- The reverse sural flap is the most commonly used soft tissue flap for the lower third of the leg and does not require microsurgical anastomosis.
- The pedicle of the reverse flap should not be skeletonized. A minimum of 5 cm should be maintained between the end of the pedicle elevation and the malleoli.
- For the reverse flap, extra length can be gained by moving the skin design more proximally toward the popliteal fossa.
- In patients who are older with peripheral vascular disease, the flap is less predictable, and surgical delay is recommended.
- Venous congestion rather than arterial ischemia tends to be the greatest problem with this flap.
- Paresthesia and the distribution of the sural nerve is well tolerated in these patients.

EXPERT COMMENTARY

Detlev Erdmann

Indications

The sural flap was initially described in 1981 as a reconstructive option for soft tissue loss of the lower extremity, particularly around the knee. This may be unknown to some of the readers, because the gastrocnemius muscle is commonly used in this scenario and is generally regarded as “standard” for this purpose. The sural flap is based on the sural artery or arteries, a medial and lateral direct branch off the popliteal artery at the level of the popliteal fossa.1

What is generally meant by “sural flap” is a variant of the reverse sural flap or distally based sural flap.2 The word sural in this context describes the sural angiosome, meaning the site where the flap’s skin island is harvested. Ever since the reverse sural flap was described by Donski and Fogdestam3 in 1983, it has been regarded as an alternative for soft tissue reconstruction of the lower extremity, particularly the lower third, and the ankle. The specific anatomic location is prone to traumatic injuries and frequently requires a free tissue transfer because of the lack of local tissues. This makes the reconstruction likely to be more challenging and time consuming, and the reverse sural flap has been welcomed by many in their search for an easy solution to the problem.

Advantages and Limitations

I have never used the originally described conventional sural flap, but I believe that a gastrocnemius muscle will better fill a typical defect located around the knee. Of major concern to me would be the additional donor site defect that has to be restored with a split-thickness skin graft. A gastrocnemius muscle donor site can be closed primarily.

The major downside of the reverse sural flap is the addition of a significant donor site defect to an already traumatized area. There are maneuvers to decrease the donor site defect, including the placement of a purse-string–type suture and grafting the donor site with a thick and nonmeshed split-thickness skin graft (sheet graft). Secondary tissue expansion and wound closure devices can also be attempted, but the possibility of a significant and unattractive donor site defect of the reversed sural flap needs to be discussed preoperatively.
A common perception about the reverse sural island flap is a high partial or complete flap loss rate. Our group reported a 36% complication rate in a high-risk patient population, including patients with diabetes mellitus, peripheral vascular disease, and venous insufficiency. This makes the reverse sural flap a secondary (inferior) choice in the perception of many surgeons. However, similar risk factors may lead to higher complication rates in lower extremity reconstruction with free tissue transfer as well.

Anatomic Considerations
The reversed sural flap is based on two main structures that are included in the adipofascial pedicle: the sural nerve and the lesser saphenous vein. Some authors have emphasized that the nerve does not contribute a crucial component of arterial inflow and may be spared in the dissection. I do not have any experience with this particular variation of flap harvest.

The main arterial flow is based on one or preferably more of the distal perforators around the lateral ankle, which are connections to the deep system, mainly the peroneal (fibular) and posterior tibial artery. Although the blood supply meets the criteria of an axial flap, the reverse sural flap pedicle does not contain a defined artery of significant size. I have not noticed a clinically relevant “superficial sural artery” in my dissections of the reverse sural flap that would allow me to perform a free tissue transfer.

Personal Experience and Insights
Because most of the partial or complete flap loss is attributable to venous congestion, maneuvers, such as designing a skin tail at the proximal portion of the flap for tension-free insetting, grafting an adipofascial pedicle, and keeping the pedicle as wide and short as possible seem to be important. Alternatively, venous supercharging has been recommended in which the proximal end of the saphenous vein is microsurgically anastomosed with a local vein close to the site of the defect.

A reverse sural flap delay procedure has been recommended by some authors to prevent flap complications. There are no data to be found in the literature that would prove superior outcomes with a flap delay over an immediate flap transfer. One main reason may be that there is no unified “delay” procedure, as our group has emphasized in the past. A delay implies redirecting blood flow either by transecting the vessel or by incising the lateral edges of the skin island.

Some surgeons prefer a pure adipofascial reverse sural flap, avoiding a skin island and grafting the adipofascia with a split-thickness skin graft. I personally do not have much experience with this flap modification, but I will consider it in the future. An ideal indication may be a defect over an intact but partially exposed Achilles tendon.

Recommendations
I think that the reverse sural island flap should no longer be regarded as a flap of secondary (inferior) choice to free tissue transfer, but as an equally valuable alternative for small and midsized defects around the ankle and heel. Exclusion criteria, in my opinion, include the creation of an additional unsightly donor site defect, and clinically obvious acute and chronic venous congestion (venous stasis).
**Planning**

The markings are made with the patient in the prone position. The first landmark in the planning of a reverse sural island flap is the lateral malleolus. A horizontal line is drawn about 5 to 6 cm above it, which represents the turning point of the flap. The adipofascial pedicle length is then planned to avoid tension on the skin island when it is placed in the defect. Planning the pedicle as wide and short as possible is essential in providing the best inflow and outflow. The skin island outline should be slightly larger than the defect to account for skin contraction, and the flap axis should be placed between the gastrocnemius muscle heads to capture the sural nerve and the lesser saphenous vein.

Outlining the distal arterial perforators to the deep system can be facilitated with a conventional acoustic Doppler system or with fluorescent angiography, a more sophisticated method.

**Technique**

The patient is placed in the prone position for preincisional markings. The first mark is a horizontal line about 5 to 6 cm above the lateral malleolus. Distal perforators may be identified with an acoustic Doppler system or fluorescent angiography at this time, but I feel this step is not absolutely essential. The defect (recipient site) is outlined with a template. Using a gauze sponge, I determine the necessary length of the pedicle. The template is then transferred to the calf, and the skin island is marked slightly larger than the defect. I like to mark a curvilinear incision from the inferior border of the skin island to the pedicle turning point instead of a straight line. A tail-type extension of the skin island can be added to the markings for tension-free inset.

![Fig. 13C-12 Design and markings for the sural flap.](image)
The incision starts at the superior border of the skin island, down to fascia. I like to preserve the lesser saphenous vein to a length of 1 to 2 cm for possible supercharging or insertion of a small intravenous catheter at the end of the procedure; the nerve is completely transected. I then proceed with incisions from superior to inferior. The skin incision above the adipofascial pedicle remains in a superficial plane into the subdermal fat. The skin flaps should not be dissected too superficially to ensure adequate perfusion, and not too deeply to preserve the adipofascial pedicle. After complete elevation to the level of the horizontal line about 5 to 6 cm above the lateral malleolus, the skin island is rotated into the defect. The skin flaps are approximated as much as possible, and the remaining adipofascial pedicle is covered with a split-thickness skin graft.

**Postoperative Care**

The leg should be rested and elevated in a below-knee, bulky plaster splint. I do not apply an external fixator, although some surgeons strongly advocate using this device. If an intravenous catheter was inserted into the lesser saphenous vein, the flap may be drained every 6 to 8 hours during the first 24 hours. The drain can then easily be removed and the vein ligated at the bedside. Sutures should remain in place for 2 to 3 weeks.

**Complications: Avoidance and Treatment**

Venous congestion with partial or complete flap loss is the most feared complication of the reversed sural flap. Leg elevation, insertion of a small intravenous catheter in the proximal stump of the lesser saphenous vein, or venous supercharging may overcome this problem. When congestion persists despite these maneuvers, the application of leeches should be considered to alleviate venous congestion.

**Take-Away Messages**

The reverse sural flap has recently gained more attention in the literature and has evolved as an alternative to free tissue transfer for soft tissue reconstruction of the lower extremity, particularly of the lower third of the leg, the ankle, and the proximal third of the foot. Venous congestion with consecutive partial or complete flap loss is the most likely reported complication of the reverse sural flap. Specific maneuvers mentioned above can help overcome this problem, but I would not recommend this flap in patients with obvious acute or chronic venous stasis.

**References**


Bibliography With Key Annotations


In this study, the authors performed single-stage reconstruction of ruptured Achilles tendons with a skin defect in six patients using a distally based superficial sural arterial flap to correct the skin component. The aponeurotic part of the proximal Achilles tendon was used. A section was taken from the midline, measuring around 2 to 2.5 cm in width and 8 to 10 cm in length, with the distal attachment intact. The tendon was rotated 180 degrees and sutured to the distal stump of the Achilles tendon without tension. The superficial sural flap procedure was carried out at the same session. The follow-up period was 9 to 30 months. All patients showed good results. One flap had necrosis of 1.5 cm of the flap, which healed well with conservative treatment.


The authors assessed the efficacy of the reverse sural artery fasciocutaneous flap in 84 patients with defects of the lower third of the leg, heel, malleoli, and hind foot. The study was conducted at the Federal Postgraduate Medical Institute Shaikh Zayed Hospital Lahore, and spanned 7 years. The patients ranged in age from 8 to 55 years. Defects were located at the distal tibia (52), Achilles tendon and posterior heel (20), malleolar region (7), anterior ankle (3), and foot amputation stumps (2). Flap dimensions ranged from 5 to 15 cm in length and 4 to 12 cm in width. All patients were followed for 6 months. Sixty-six flaps survived completely, with marginal necrosis in six patients and infection in four patients. Complete flap necrosis occurred in eight flaps. Donor site morbidity was minimal. The functional outcome was satisfactory in all patients. The technique was safe, of short duration, and an alternative to microsurgical reconstruction.


In this report, the authors introduced the “neural-island flap” concept, which represented a consistent, reliable skin flap design supplied only by the intrinsic vasculature of a cutaneous nerve. Its advantages include a very narrow pedicle without any restriction to a specific pivot point, preservation of a major artery, and avoidance of microvascular anastomoses. The flap was studied in 92 rats. The pedicle was the lateral femoral cutaneous nerve. A standard skin flap was elevated on the lower dorsal region. This flap was the territory of the accompanying vessels, the iliac branches of the iliolumbar artery and vein. Results demonstrated consistent perineural vasculature by the iliolumbar artery. Skin flaps survived totally when the artery and vein were intact. Survival was significantly higher for the
delayed neural-island flap compared with the acutely elevated neural island flap. The perineural and intraneural vessels were greatly dilated after a delay procedure. Based on these results, the authors developed a clinical technique using the sural neural-island flap and performed the flap to reconstruct lower extremity defects in four cases. A delay procedure was accomplished in the first stage by elevating a fasciocutaneous flap from the midcalf region based on a posterior skin bridge and the sural nerve. After a 2-week delay period, a sural neural-island flap was created based on the nerve and transposed to the defect. All flaps survived completely, with satisfactory results.


To assess the efficacy of the distally based sural flap for distal-third lower leg defect, the authors studied the vascular anatomy surrounding the sural nerve in 20 cadavers. The flap was elevated, and the femoral arteries were injected with barium and analyzed histologically. Angiography showed that small extrinsic vessels around the sural nerve and the lesser saphenous vein were important, especially in flap transfer. Those around the sural nerve seemed to have the most influence on flap survival. The authors also reviewed outcomes in 28 consecutive cases. The deep fascia and lesser saphenous vein were included in all flaps, but the sural nerve was excluded to prevent paresthesia. Twenty-two flaps survived completely. Distal partial necrosis occurred in five flaps, and total necrosis in one flap. Findings suggested that the sural nerve could be preserved to avoid surgically inducing paresthesia.


The authors performed the reverse sural artery flap in 70 high-risk, critically multimorbid, and older patients. The necrosis rate was 36%. They presented a detailed, critical, retrospective complication analysis. Risk factors that could impair successful defect coverage were concomitant diseases, particularly diabetes mellitus; peripheral arterial disease or venous insufficiency, which increases the risk of flap necrosis fivefold to sixfold; and patient age over 40 years. Age alone did not apparently represent a risk factor. To overcome some of these risk factors, the authors modified their procedure. They recommended (1) a delay procedure, or not using this flap at all, if the lesser saphenous vein cannot be located and (2) an external fixation device to facilitate postoperative care for most patients.


The free peroneal perforator–based sural neurofasciocutaneous flap was transferred in six patients with soft tissue defects of the forearm and hand. Patient ages ranged from 22 to 51 years. One patient had a skin defect of the hand; two had skin defects of the hand, with tendon injuries and metacarpal fractures; two had skin defects of the forearm; and one had forearm skin defects with radial and ulnar fractures. Free flaps were transferred 4 to 7 days after the emergent treatment. Flaps were designed along the axis of the sural nerve nutrient vessels, with the peroneal perforator above the lateral malleolus as the pedicle, with a part of the peroneal artery for vascular anastomosis. The peroneal artery was anastomosed to the radial (or ulnar) artery, and the peroneal veins were anastomosed to one of the radial (or ulnar) veins and the cephalic vein, respectively. The flap size ranged from 8 by 18 cm to 12 by 12 cm. Donor areas were closed with skin grafts. Patients were followed for 6 to 13 months. Five flaps survived. One had partial, inadequate venous return and distal superficial necrosis, which resolved with dressing changes and antinfective therapy. All patients had satisfactory aesthetic and functional outcomes.


The distally based sural fasciocutaneous flap was transferred in 15 patients with soft tissue defects of the ankle and/or foot. The vascular pedicle of the flap included the terminal perforator branch of the peroneal artery and concomitant veins. The pivot point was approximately 5 cm above the tip of the lateral malleolus. The flaps measured 8 by 9 cm to 13 by 31 cm. Thirteen flaps survived completely, and two had partial or marginal necrosis. Texture match and contour were good.

The authors modified the distally based sural fasciocutaneous flap to reconstruct foot and ankle soft tissue defects in seven patients. The vascular pedicle included an axial perforator branch of the peroneal artery and two venae comitantes. The flap measured about 17 by 6 cm to 30 by 10 cm. All flaps survived completely. Neither arterial ischemia nor venous congestion was noted. This modified sural flap has an easily rotated, thin perforator pedicle, with a good blood supply through axial perforator and longitudinal chain-linked vascular plexuses.


Shallow defects over the ankle and foot can be difficult to correct. The authors reported their experience using two variants of the free medial sural artery perforator flap from the medial aspect of the upper calf for this purpose in 13 patients. This flap preserved the medial gastrocnemius muscle to avoid unnecessary bulkiness, had a long pedicle, and was thin and pliable. The skin defects were combined with bone, joint, or tendon exposure. Major arteries were preserved. The disadvantages included the tedious process of intramuscular retrograde dissection of the perforator and the unappealing skin graft over the medial calf.


The radial forearm flap has long been considered the first choice for intraoral reconstruction; however, donor site morbidity led to the search for another primarily thinned flap for this purpose. The authors used the free medial sural artery perforator flap to reconstruct intraoral defects in 22 patients after cancer ablation. The locations were the tongue and floor of mouth (15), buccal mucosa (5), retromolar trigone (1), and anterior floor of mouth (1). The major perforator (vein 1 mm or larger) was endoscopically confirmed. The skin paddle ranged from 7.5 by 4 cm to 17 by 8 cm. The flap provided thin, pliable coverage, with minimal donor site morbidity. The medial gastrocnemius muscle was preserved.


The distribution of the dominant perforators of the peroneal artery (DPPA) were assessed by color Doppler flow imaging (CDFI) in both legs of 20 healthy volunteers. The numbers, diameters, and locations of the perforators were analyzed. Based on these results, the authors designed and transferred 51 free or pedicled sural neurocutaneous flaps supplied by a single dominant perforator of the peroneal artery to repair the defects near the ankle (22), in the leg (15), and in the forefoot or hand dorsum (14). All perforators were located preoperatively with CDFI, with accuracy confirmed intraoperatively. The average number of DPPAs, their size, and their locations were recorded. The causes of false results were analyzed. All 51 flaps were successful. No necrosis or other vascular problems occurred. Preoperative CDFI had a 93.6% true-positive rate and an 88% positive predictive value. The authors concluded that a sural neurocutaneous flap pedicled with one of these relatively large perforators can be utilized to repair skin defects of the leg and ankle, but not of the forefoot. Based on the largest DPPA, with anastomosis of the perforator, this flap can be used as a free flap to cover numerous defects. CDFI facilitates the surgical procedure.


The proximally based sural artery flap is useful for reconstructing soft tissue defects around the knee and proximal and middle thirds of the lower leg. In this article, the authors discussed their results using this flap in 10 patients. Defects were located at the knee (4), on the proximal third of the lower leg (4), and on the middle third (2). Eight fasciocutaneous flaps and two adipofascial flaps were performed. The flap ranged from 4 to 10 cm to 5 by 8 cm. The pedicle length ranged from 12 to 20 cm. All flaps survived. Complications consisted of congestion and tip necrosis in one fasciocutaneous flap, and
a superficial infection in one fasciocutaneous flap. Both healed without further complications. Two adipofascial flaps had necrosis of grafted skin; one required additional surgery. No donor site morbidity or functional deficits were noted.


Most articles about the sural flap pertain to soft tissue defects at the lower leg and foot. Some authors have shown that the lesser saphenous vein and its accompanying artery are important in vascularizing the posterior skin of the leg, resulting in a more proximal flap design, with a longer arc of rotation. In this article, the authors share their results of 13 cases of distally based sural flaps. The flap was harvested either distal (group A: all soft tissue defects were in the lower leg and foot) or proximal (group B: defects involved the anterior tibia) to the midpoint of the leg. In group A, the complication rate was 33.33%, and the flap survival rate was 83.33%. In group B, the complication rate was 42.85%, and the survival rate was 100%.


Although the sural flap has been used as an alternative to free tissue transfer for soft tissue coverage in the lower extremity, flap failure rates can be increased in patients age 40 years or older, and in those with other risk factors such as peripheral artery disease, venous insufficiency, and diabetes mellitus. The authors described a sural flap delay procedure to avoid flap necrosis in these patients.


Gill NA, Hameed A. The sural compendium: reconstruction of complex soft-tissue defects of leg and foot by utilizing the posterior calf tissue. Ann Plast Surg 2011 Jul 5. [Epub ahead of print]

The sural flap is considered by many as the workhorse for soft tissue coverage in the knee, leg, ankle, heel, and foot. The authors introduced a simple algorithm for reconstructing these defects with this flap. Over the course of 9 years, they performed a variety of sural flaps (67 delay procedures) in the lower limb in 168 patients, aged 4 to 75. Of 168 flaps, 154 survived completely, 9 had partial necrosis, and 5 failed completely.


A chimeric form of combined flap can be beneficial in some cases by using any muscle perforator flap and its underlying muscle as a branch-based form of chimeric flap. The authors applied this concept in two patients with knee infections. They used only local flaps to simultaneously allow deep obliteration within the knee joint with the muscle portion and tension-free skin closure. A chimeric gastrocnemius muscle and sural artery perforator flap were utilized, the latter based on either the medial or lateral sural source vessels.


The authors performed revascularization and wound reconstruction with a reverse sural artery fasciocutaneous flap to salvage limbs in 9 patients with ischemia. All flaps healed primarily. Donor site complications were minimal. All limbs were functioning 6 months postoperatively. Wound dimensions and the presence of preserved blood flow must be seriously considered for this procedure. This method warrants consideration, when appropriate, over revascularization and microsurgical transplantation.


Seven patients with ankle or heel defects had unsuccessful results with conservative treatment. The authors performed a distally based neurofasciocutaneous sural artery flap. The presence of a patent peroneal artery was a requirement. One flap failed in an immunocompromised renal transplant patient. All others healed uneventfully. These six patients resumed full weight-bearing status. The average healing time for all patients was 3.3 months.


The perforator topography of the medial sural artery perforator flap and its clinical application in head and neck reconstruction were examined in 29 patients. Twenty-six patients had head and neck reconstruction using medial sural artery perforator flaps. Flap sizes ranged from 8 by 4 cm to 12 by 14 cm. The following parameters were recorded: mean pedicle length, mean flap thickness, mean number of total perforators, mean number of sizable perforators, and mean distance of the perforator to the popliteal crease. Most sizable perforators (85.4%) entered the medial gastrocnemius muscle at a fifth to a third of the lower leg length measured from the popliteal crease. All but one flap survived, with good functional and aesthetic outcomes. Advantages of this flap were discussed.


The free medial sural artery perforator flap has recently been used as an alternative to the free radial forearm flap for small to medium-sized defects after head and neck reconstruction after cancer ablation. The authors studied outcome and donor site morbidity with these flaps in 47 patients, aged 30 to 70 years. The free medial sural artery perforator flap was used in 18 cases, and the free radial forearm flap in 29 patients. All flaps were successful. There was no significant difference in flap harvest time, hospital stay, or overall recipient site complication rate. The subjective functional and cosmetic outcome was better in patients with the free medial sural artery perforator flap (two-sided Fisher's exact test). This flap resulted in less donor site morbidity.


The authors reconstructed facial nerve and soft tissue defects resulting from malignant tumor resection in three patients using a fasciocutaneous flap designed in the posterior calf region. The flap included the vascularized sural nerve and was elevated based on the perforating artery of the gastrocnemius. Results were satisfactory, and facial animation returned in two patients who were followed for 6 months or longer. The advantages of this compound flap included a long vascular pedicle with sufficient diameter and ample blood supply for the sural nerve and fasciocutaneous flap. This new technique is an option for vascularized sural nerve grafts when the superficial sural artery or the cutaneous branches of the peroneal artery are not adequate for flap elevation or microsurgical anastomoses.


The medial sural artery perforator free flap was presented as an option for soft tissue coverage of plantar defects. The authors transferred this flap in 11 patients, aged 10 to 68 years. The follow-up was 7 to 22 months. The flap size ranged from 10 to 14 cm by 5 to 7 cm. All flaps survived. One flap had marginal loss distally, and this was treated successfully with a split-thickness skin graft. Venous insufficiency developed in one flap and was successfully treated with leeches. All flaps had protective sensation at the long-term follow-up. Despite its thinness, this flap was sufficiently durable for weight-bearing areas.

Defects of the distal third of the leg and foot are challenging cases for reconstructive surgeons because of the limited mobility and availability of overlying skin, the weight-bearing requirements, and the relatively poor circulation of the skin. This article focuses on the authors’ experience using a two-stage expanded reverse sural flap in 10 patients with defects of the foot and ankle. Six patients had at least one risk factor such as diabetes mellitus, peripheral arterial disease, venous insufficiency, tobacco smoking, or age 40 years or older. Complications included flap necrosis in one patient and venous congestion in two patients (one responded to postural elevation of the extremity and one to medicinal leech therapy). The authors recommended this flap for defects too large to be primarily closed, especially in patients with risk factors listed previously.


The authors share their results from 14 patients in whom a free medial sural artery perforator flap was transferred for hand reconstruction. Defect locations were the digits (7), dorsal hand (3), palmar hand (2), and wrist (2). Five patients had tendon and nerve defects. Although the donor site provided only a thin fasciocutaneous flap, the authors also harvested the plantaris tendon (4), split Achilles tendon (1), saphenous nerve (1), and sural nerve (1) from the same donor site for one-stage, composite tissue reconstruction. The proximal perforator of the medial sural artery emerged 8 to 13 cm from the midpoint of the popliteal crease. This location correlated with the axis of the medial sural artery. Twelve flaps were raised with a single perforator. One flap failed because of perioperative vasospasm. The donor defect was closed without skin grafts for flaps less than 6 cm in width. The authors recommended this flap for small to medium-sized defects of the hand.


In patients with traumatic limb injuries, vein grafts are often required to bridge the gap of the artery, vein, or both. One option is a temporary arteriovenous fistula (AVF) that, once matured, is divided and used as recipient artery and veins for the free flap. The vein graft length, vein graft diameter, and arterial inflow influence the patency of the vessels and the final outcome. The authors reconstructed 65 defects using free tissue transfers, using vein grafts of significant length (20 cm or longer for the arterial gap). For all patients, the ipsilateral or contralateral great saphenous veins were utilized to lengthen vessels. Inflow arteries were either major arteries (superficial femoral, popliteal, or brachial), or lesser arteries (sural, anterior or posterior tibial, thoracodorsal, or superior gluteal). Six patients underwent AVF followed by free tissue transfer in two stages, and 28 patients had AVF followed by free tissue transfer in one stage. Thirty-one patients underwent vein grafting for the arterial defect only—6 with and 25 without a simultaneous bypass graft for lower limb revascularization. The authors concluded that one-stage AVFs can be used with good results; however, two-stage AVFs are associated with a high graft occlusion rate, wound failure rate, and limb amputation rate. For all patients in this study, a large-caliber graft such as the great saphenous vein provided a large (relatively low resistance) conduit for bridging the defect.


The major disadvantage of the reverse sural artery flap for reconstructing the distal third of the leg, ankle, and heel is compression of the pedicle within the subcutaneous tunnel and venous congestion. The authors described a two-stage technique for this flap whereby a subcutaneous tunnel is avoided and the pedicle is exteriorized with no other alterations to flap design or elevation techniques. They performed seven distally based reverse sural artery flaps on ambulatory patients, with no resultant venous congestion in any flaps. None of the patients required a custom shoe, and all were ambulatory after surgery.

The authors studied the vascular anatomy of the sural flap in 24 amputated limbs of patients with arteriopathy. The mean patient age was 68.5 years. The clinical signs of arteriopathy had been present for 3 to 16 years. Amputation was performed directly in 10 cases, and after failed revascularization in 14 cases. Based on dissection results, a sural flap was theoretically possible in 23 of 24 cases. The authors proposed that the progressive evolution of arteriopathy and the concomitant development of a supply network involving the vascularization of the sensory nerves leads to the “anticipation” of a sural flap.


The authors conducted an anatomic study to determine which parts of the distally based superficial sural artery flap were essential to the flap’s arterial supply. They examined 24 fresh, adult cadaver legs. They harvested 32 flaps: cutaneous-venoneuroadipofascial (5), venoneuroadipofascial (3), neurofascial (4), cutaneous-adiovenous (2), cutaneous-venoedipofascial (9), venoedipofascial (5), and purely fascial (4). Barium sulfate was injected into 28 flaps, and CT was used to determine the vascular territory of each flap. Leg length, location of the sural nerve crossing the deep fascia, and location of peroneal and posterior tibial artery perforators were recorded. The cutaneous-venoedipofascial and cutaneous-venoedipofascial flaps were the best perfused, and the neurofascial and purely fascial flaps were the least perfused, having only a perineural vascular network, with minimal fascial contribution.

The authors concluded that the lesser saphenous vein and the deep adipose tissue are necessary for the arterial supply of the sural flap. The deep fascia provided only mechanical support. The sural nerve contributed to the vascular network, but including it did not increase the vascular territory.


To minimize complications from superficial sural artery flaps used to reconstruct defects of the lower leg and proximal foot, the authors performed 12 distally based neurovascular sural flaps for heel, ankle, and lower leg defects. An additional arteriogram was done preoperatively to confirm patency of the peroneal artery. Acoustic Doppler ultrasound was used to identify the lesser saphenous vein and the concomitant vessels (perforators of the peroneal artery) of the sural nerve. To decrease pressure on the vessels and facilitate primary closure, an enlarged skin paddle was harvested with a tail of skin over the pedicle at the point of rotation. Postoperatively, external fixation ensured strict immobilization.

All flaps survived. A few minor complications occurred.


Surgical technique, complications, and outcomes were analyzed from 102 patients who underwent treatment for jugular foramen tumors. All treatments combined neurosurgical and ear, nose, and throat techniques. Preoperative embolization was performed for paragangliomas and other highly vascularized lesions. Surgical defects were reconstructed with specially developed vascularized flaps (temporalis...
fascia, cervical fascia, sternocleidomastoid muscle, and temporalis muscle) to prevent postoperative CSF leakage and to optimize the aesthetic outcome. Paraganglioma (58) was most common, followed by schwannomas (17), and meningiomas (10). Complete excision was possible in 45 patients with paragangliomas and in all patients with schwannomas. Lower cranial nerve deficit was the most common and most dangerous complication (10). Postoperative facial and cochlear nerve paralysis occurred in eight patients. Three recovered spontaneously, and the facial nerve was reconstructed using nerve grafts in the others. Four patients had postoperative CSF leakage, and four died after surgery—two of aspiration pneumonia complicated with septicemia, one of pulmonary embolism, and one of cerebral hypoxia caused by a large cervical hematoma that led to tracheal deviation. Radical removal of benign jugular foramen tumors is the treatment of choice, may be curative, and has low mortality and morbidity rates. Postoperative lower cranial nerves deficits are the most dangerous complication.


The authors presented results in 40 patients with soft tissue defects of the lower leg that were treated with sural flaps, either a long pedicled flap or an islanded flap. Patient age ranges from 4 to 75 years. Using this versatile flap with its wide arc of rotation resulted in minimal flap loss.


The authors transferred a distally based sural flap in four patients to reconstruct soft tissue defects in the lower leg and foot. All flaps survived completely. The authors recommended including both the sural nerve and the lesser saphenous vein in the flap, as well as the surrounding fatty tissues in the pedicle. This procedure was carried out in a single surgery and required minimal time. Although the sural nerve had to be sacrificed, the major arteries in the leg were maintained.


The proximally based sural artery flap was used to reconstruct lower knee, thigh, and upper leg defects resulting from tumor excision in 37 patients. The authors reviewed their results. All flaps were successful, except one that developed distal marginal necrosis. A bipedicled flap successfully corrected this complication. All donor sites were closed with split-thickness skin grafts. The final outcome was good in all patients. The authors concluded that this technique was simple and reproducible. It provided good reach and thin, pliable skin.


To enhance the anatomic knowledge of the medial posterior calf region and to devise a plan to facilitate the medial sural artery perforator flap technique, the authors studied the anatomy of 20 fresh lower limbs. After injecting resin into the popliteal artery, they sculpted flaps according to anatomic markings. The following parameters were recorded: average flap dimensions; number, diameter, location, and origin of perforators; and configurations of the intramuscular course of the perforators, of which there were two.


This article focuses on the axiality of the distally based sural artery flap based on the sural nerve and the short saphenous vein. The authors performed 40 flaps for a variety of defects in the distal leg. In the proximal leg, they explored the groove between the medial and lateral heads of the gastrocnemius muscle and included the subfascial part of the medial sural nerve with the flap. The subfascial part of the nerve could consistently be included with the flap to provide cutaneous supply to the tip of the flap. The short saphenous vein could be harvested with additional length for supercharging or intermittent bleeding in the event of flap congestion. Their success rate with this flap was 98%.

In this study, the authors’ goal was to determine a better method for repairing skin and soft tissue defects in the lower leg, ankle, and foot in emergency situations. They performed island fasciocutaneous flaps supplied by the superficial sural artery in 18 patients with these defects. The flap was designed on the posterior aspect of the leg. It ranged in size from 4 by 5 cm to 11 by 12 cm. Sixteen flaps survived completely, and two had partial necrosis. At the 2-year follow-up, results were satisfactory in the 16 patients with complete flap survival.

Xie XT, Chai YM. Medial sural artery perforator flap. Ann Plast Surg 2011 Apr 4. [Epub ahead of print]

The medial sural artery perforator flap can be designed as a pedicled, free, or chimeric flap, or may be used in sequential order. Its versatility has made it a popular reconstructive option for various body areas. Anatomic anomalies of the perforators are rare compared with other perforator flaps. Nevertheless, meticulous preoperative planning and perforator identification are essential for successful flap harvest. The authors reviewed the anatomy, preoperative planning and flap design, harvest technique, and clinical applications of this flap in multiple body sites. Advantages and disadvantages were presented.


In this study, the authors’ aim was to document the vascular anatomy of the distally based superficial sural artery flap and better understand the vascular anastomoses between the superficial sural artery and the septocutaneous perforators of the peroneal artery. They examined 10 fresh human cadavers (20 legs) that were injected with lead oxide, gelatin, and water. They found a constant vascular anastomosis between the superficial sural artery and the lowest septocutaneous perforator of the peroneal artery. They also performed the distally based superficial sural artery island flap in 26 cases. Twenty-four flaps survived uneventfully, and two developed partial fat necrosis.


Conventional reversed sural flaps often result in distal marginal flap necrosis when the flap is utilized to cover soft tissue defect located at the dorsum of the metatarsophalangeal joint. The authors’ goal was to report on a new method to augment the blood supply of the flap. They found a constant cutaneous branch from the peroneal artery 11 ± 1.7 cm from the lateral malleolus, and performed 10 modified distally based reverse sural artery flaps incorporating this branch. All of the flaps survived completely.


The authors attempted to modify the distally based flap pedicled with the nutrient vessel of the lower rotation point of the sural nerve to reconstruct soft tissue defects in the foreleg. This flap was not appropriate for cases with complex bone defects. They studied a compound flap pedicled with the sural nerve and the lesser saphenous veins in the lower extremities of 30 human cadavers. They found that the sural lateral artery, the peroneal artery, the lateral posterior malleolus artery, the perforating branches of the heel lateral artery, and the myocutaneous perforators from the gastrocnemius formed a vascular chain for the sural nerve and lesser saphenous vein. Based on these results, they performed distally based compound flaps of sural nerve and lesser saphenous vein in 20 patients. The myocutaneous flap was used in patients with lower leg ulcers, osteomyelitis, or bone exposures (10), and medial calcaneal osteomyelitis (3). Osteocutaneous and myocutaneous flaps were used for tibial bone defects (7). The authors concluded that the distally based compound flap pedicled with the nutrient vessel of the sural nerve and lesser saphenous vein was convenient and reliable because it offered the advantages of infection control and rapid healing. It could be satisfactorily modified to reconstruct leg bone defects, missing skin, and foot and ankle defects.
## ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th><strong>Landmarks</strong></th>
<th>Posterior calf; the most superficial muscle of the upper third of the leg, with tendinous extension to the heel.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>20 × 8 cm.</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>Medial head: medial condyle of the femur; lateral head: lateral condyle of the femur.</td>
</tr>
<tr>
<td><strong>Insertion</strong></td>
<td>Calcaneus through the Achilles tendon.</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Plantar flexion of the foot.</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Muscle.</td>
</tr>
<tr>
<td><strong>Flap Type</strong></td>
<td>Type I.</td>
</tr>
<tr>
<td><strong>Dominant Pedicles</strong></td>
<td>Medial and lateral sural arteries.</td>
</tr>
<tr>
<td><strong>Nerve Supply</strong></td>
<td><em>Motor</em>: Branches of the tibial nerve.</td>
</tr>
</tbody>
</table>
Section 13D

LEG

Gastrocnemius Flap

CLINICAL APPLICATIONS

Regional Use
- Inferior thigh
- Knee
- Lower extremity (upper third)

Specialized Use
- Functional muscle transfer
Fig. 13D-1

**Dominant pedicles:** Medial gastrocnemius, medial sural artery; lateral gastrocnemius, lateral sural artery
ANATOMY

Landmarks The most superficial muscle of the calf posteriorly. Its muscle belly occupies the upper third of the leg, and its tendon extends to the heel.

Composition Muscle. There are two distinct heads: medial and lateral. The medial head is the larger of the two, and its fibers extend more inferiorly.

Size $20 \times 8$ cm.

Origin Medial head: medial condyle of the femur; lateral head: lateral condyle of the femur.

Insertion The muscles have a common insertion into the calcaneus through the Achilles tendon. This is a fused common tendon with the soleus muscle.

Function Plantar flexion of the foot. To preserve this function, either or both heads of the gastrocnemius may be sacrificed if the soleus muscle is intact.

Arterial Anatomy (Type I)

Dominant Pedicle *Medial gastrocnemius: medial sural artery*

**REGIONAL SOURCE** Popliteal artery.
**LENGTH** 6 cm.
**DIAMETER** 2 mm.
**LOCATION** Popliteal fossa.

Dominant Pedicle *Lateral gastrocnemius: lateral sural artery*

**REGIONAL SOURCE** Popliteal artery.
**LENGTH** 6 cm.
**DIAMETER** 2 mm.
**LOCATION** Popliteal fossa.

Venous Anatomy

Venous anatomy accompanies the named sural vessels as venae comitantes.

Nerve Supply

Motor Branches of the tibial nerve. Paired motor nerves enter the deep surface of the medial and lateral heads of the muscle within the popliteal fossa just posterior to the vascular pedicles.
Vascular Anatomy of the Gastrocnemius Flap

**Fig. 13D-2**

**Dominant pedicles:** Medial gastrocnemius, medial sural artery ($D_1$); lateral gastrocnemius, lateral sural artery ($D_2$)

- a, Medial gastrocnemius muscle; b, lateral gastrocnemius muscle; m, anastomotic vessels between muscle heads; n, sural nerve; p, plantaris tendon; s, soleus muscle
Deep surface of medial flap  

Radiographic view

**Fig. 13D-2**

**Dominant pedicle:** Medial gastrocnemius, medial sural artery ($D_1$)

$m$, Anastomotic vessels between muscle heads
Fig. 13D-2

**Dominant pedicle:** Lateral gastrocnemius, medial sural artery ($D_2$)
m, Anastomotic vessels between muscle heads
**FLAP HARVEST**

**Design and Markings**
The skin overlying the gastrocnemius muscle can be elevated from an incision directly over each muscle or through a midline stocking-seam incision. The stocking-seam incision allows access to both heads of the muscle. Direct incisions over the muscles, approximately 2 cm posterior to the tibia (medial head) or fibula (lateral head). Sometimes the muscle can be elevated through the wound or defect that is to be reconstructed.

**Patient Positioning**
The patient is placed in the supine position with the leg either internally or externally rotated, depending on which muscle is being exposed. The patient may also be placed in a lateral decubitus position for elevation of either muscle, or prone for free flap harvest.

**GUIDE TO FLAP DISSECTION**

**Medial Gastrocnemius**
The muscle is exposed through either a posterior midline (stocking-seam) incision or an incision directly overlying the muscle. The skin is undermined and the superficial surface of the muscle is exposed.

**Fig. 13D-3** Dissection of the gastrocnemius muscle using a stocking-seam incision or direct incision.

**Fig. 13D-4** A, Medial head of the gastrocnemius muscle, with the sural nerve at its lateral border.
The gastrocnemius is separated from the soleus in an areolar plane that can be dissected digitally to identify the space. Dissection starts at the medial edge of the muscle where the plantaris tendon is visualized between the gastrocnemius and soleus muscles. Dissection then proceeds inferiorly, where the muscle is fused with the Achilles tendon. The medial half of the Achilles tendon is incised, leaving only a 1 cm cuff of tendon on the muscle flap. Next, the raphe between the medial and lateral muscles is visualized. The lesser saphenous vein and sural nerve are visualized and preserved, then retracted laterally to allow division of the medial and lateral gastrocnemius. This midline point is sharply incised to separate the medial gastrocnemius muscle.

Fig. 13D-4  B, The medial head is converted into a true island flap by division at its origin from the femur. The fascia is dense on the undersurface of the muscle. This fascia can be scored or completely excised to expand the area of muscle coverage.

The arc of rotation is tested at this point, and if mobilization is adequate, the muscle can be secured. For greater arc of rotation, further proximal dissection is performed and the sural vessels identified. The origin of the muscle is sharply divided, protecting the vascular pedicle.

Fig. 13D-4  C, Both the tibial tubercle and the patella are easily covered by the medial head.
Lateral Gastrocnemius
The muscle is exposed through a vertical incision along the proximal middle third of the leg directly overlying the muscle or in the posterior midline. Subcutaneous tissues are dissected away, and the surface of the muscle is exposed. The lesser saphenous vein and the sural nerve are identified, helping to determine the posterior midline. These structures are preserved. The lateral border of the muscle is identified, and the gastrocnemius is separated from the underlying soleus muscle first with blunt finger dissection in an areolar plane.

Dissection proceeds inferiorly, where the muscle insertion at the Achilles tendon is reached. This lateral Achilles is divided, leaving a 1 cm cuff of tendon with the muscle flap. The flap can now be elevated, and the deep surface of the muscle is seen. The raphe between the medial and lateral gastrocnemius heads is identified, and this raphe is sharply divided to allow rotation of the lateral gastrocnemius flap at its origin. Care is taken on the lateral side not to injure the superficial peroneal nerve as it passes in close proximity to the superficial surface of the muscle origin. For greater arc of rotation, the vascular pedicle must be isolated on the deep surface. Once this pedicle is visualized and protected, the lateral fascial fibers of origin from the lateral condyle of the femur can be divided, increasing the arc of rotation.

FLAP VARIANTS
- Myocutaneous flap
- Functional muscle transfer
Myocutaneous Flap
Although the skin overlying each of the heads of the muscle can be taken with the flap, the donor site created is unaesthetic and often requires skin grafting. Instead, it is recommended that the gastrocnemius flap be transferred as a muscle-only flap and grafted at its recipient site. This allows primary closure and best aesthetics in the leg and allows easier flap inset and closure.

Functional Muscle Transfer
Although the harvest of either head of the gastrocnemius as a free innervated muscle flap has been described, other muscle flaps have longer neurovascular pedicles with little donor morbidity and are thus preferred (that is, the gracilis, pectoralis minor, latissimus, and rectus).

ARC OF ROTATION
Medial Gastrocnemius
The arc of rotation will cover defects of the inferior thigh (the suprapatellar region), knee, and upper third of the tibia.

The origin of the medial head of the medial condyle of the femur can be divided, releasing the muscle and extending the arc of rotation by 5 cm, which permits more effective coverage of the knee and distal thigh.
Lateral Gastrocnemius

The arc of rotation of the lateral gastrocnemius will allow coverage of defects of the inferior thigh (the suprapatellar region), knee, and proximal third of the tibia.
Division of the origin of the lateral head of the lateral condyle of the femur will release the muscle and extend the arc of rotation by 5 cm, permitting more effective coverage of the knee and distal thigh.

**FLAP TRANSFER**
The incision for harvesting the flap will ultimately dictate whether a tunnel is required or whether the muscle is transposed through a direct communication between the donor site and the recipient site. Neither is preferred; if a subcutaneous tunnel is created, the tunnel must be wide enough to permit good perfusion of the muscle and allow for postoperative swelling.

**FLAP INSET**
The surgeon should take advantage of the 1 cm cuff of fascia that has been taken from the Achilles tendon to allow the tension of the flap closure to be borne by this tissue to create a tension-free closure. All dead space should be filled, and any surrounding skin should be tacked down to the muscle surface. Scoring and removal of the fascia of the gastrocnemius muscle are recommended to ensure the best skin graft take.

**DONOR SITE CLOSURE**
The donor site should be closed primarily in all cases. If a connection has been made between the donor and recipient sites, the pedicle may be either buried and closed over, or skin grafted. The surgeon should make the closure decision to minimize complications, such as compression of the pedicle.
CLINICAL APPLICATIONS
This 24-year-old man had an upper third defect of the leg as a result of a motorcycle accident. There was loss of both bone and skin. The results of a distal vascular examination were normal.

Fig. 13D-8  A, The defect was largely in the upper third, seen here after aggressive debridement. Methylmethacrylate spacers were placed for two-stage bony reconstruction. A medial gastrocnemius flap was planned. B, The medial gastrocnemius was elevated from within the wound. After scoring the muscle fascia for extended coverage, the origin did not require division. This was preferred to protect the pedicle postoperatively from undue tension. C, The flap was transposed, completely covering the exposed spacers. D, The leg is seen 2 months postoperatively with uncomplicated healing and a nice contour. (Case supplied by MRZ.)
This 27-year-old man was involved in a motor vehicle accident and was seen 3 weeks after the accident for a gastrocnemius flap repair after recovering from his other injuries. Most of the wound would accept a skin graft, but the one open area had exposed, devitalized bone that required debridement.

**Fig. 13D-9**  
A, The wound at presentation. Although the wound appears small, it contained dead bone and was larger after debridement, with an associated dead space. B, After elevation of the medial gastrocnemius flap and inset, obliterating the cavity. The muscle and the surrounding bed were then skin grafted. C, Oblique and D, AP views of the leg at 4 weeks postoperatively. The wounds healed completely without the need for revisions. (Case supplied by MRZ.)
Use of the gastrocnemius can result in good aesthetics if planned well. This is demonstrated in this upper third open tibial fracture with a soft tissue defect after a motor vehicle accident.

Fig. 13D-10  A, A medial gastrocnemius flap for an upper third defect. B, At inset, the surrounding skin was undermined, allowing inset of the muscle beyond the wound edges and leveling the surface contour. This is also helpful if some skin edge should necrose, since underlying healthy muscle will be exposed. C, Wound at 1 month postoperatively, already showing an excellent contour. D, The patient’s leg has excellent aesthetics and function at 9 months. (Case supplied by MRZ.)
This 25-year-old man sustained a crush injury to his leg in a motor vehicle accident, fracturing his tibia and fibula without vascular injury.

![Image](image_url)

**Fig. 13D-11**  
A, The wound is seen 2 weeks after the patient's accident, after stabilization from his other injuries. There is a large upper and middle third of the leg skin defect, with exposed devitalized bone and granulation tissue.  
B, His arteriogram showed intact vessels to the foot. The comminuted fracture of the fibula is seen.  
C, After aggressive debridement of devitalized tissues, significant defects of the upper and middle thirds of the leg remained. Also, staged bone grafting was desired, so muscle flaps were designed to cover the entire defect with viable muscle. The medial gastrocnemius was harvested for the upper third defect, and the medial hemisoleus was harvested for the middle third defect. Note the scoring of the muscular fascia to extend reach and wound coverage.  
D, Flaps transposed into the defect, providing total muscle coverage of the wound. The surface of the muscle was skin grafted.  
E, The patient is seen 2 weeks postoperatively, with uncomplicated healing. (Case supplied by MRZ.)
Pearls and Pitfalls

- Plantar flexion can be maintained when both heads of the gastrocnemius are taken if the soleus muscle is intact. Alternatively, one head can be taken, with a hemisoleus muscle still maintaining function.
- Reverse flaps and V-Y advancement flaps, which were employed in the past, are unreliable and should not be performed.
- Piecrusting or resection of the fascia on either side of the gastrocnemius muscle will allow expansion of the muscle to cover a greater surface area and also give the added benefit of allowing skin graft take. To minimize graft movement and increase graft take, use of a negative-pressure wound therapy is recommended.
- A tourniquet may be used during elevation of the flap to allow identification of important nerves, such as the peroneal and tibial nerves.
- The medial head of the gastrocnemius muscle is usually preferred to the lateral head for flap repair because of its larger size, greater arc of rotation, and avoidance of the peroneal nerve.
- In traumatic injuries, preoperative arteriography can be helpful in establishing patency of the sural vessels before the muscle is elevated.
- A history of recent deep venous thrombosis or active DVT in the lower extremity is a contraindication to the use of the gastrocnemius flap.

EXPERT COMMENTARY

Glyn Jones

Indications
The gastrocnemius muscles are most commonly used to cover proximal tibial and anterior knee defects. In most cases, they are used to cover open fractures or exposed bone following trauma, tumor resection, or in the treatment of osteomyelitis. Knee coverage is usually needed after exposure of components from skin necrosis or infection after knee arthroplasty.

Advantages
The medial gastrocnemius is the bigger and the longer of the two heads and is most easily used for tibial coverage and anterior or medial knee coverage. The smaller and shorter lateral head is best reserved for lateral knee defects that cannot be reached with the medial head transposition. It can also be used (as can the medial head) for popliteal defects that have not damaged the sural artery inflow. Lateral head elevation is complicated by the presence of the common peroneal nerve, which has to be very carefully dissected to prevent neurapraxia and footdrop.

Anatomic Considerations
The medial head of the gastrocnemius, as mentioned earlier, is longer and thicker than its counterpart; therefore its arc of rotation is longer. Scoring of the deep fascial surface of the muscle will allow significant expansion, particularly in its transverse diameter, which allows a greater area of coverage. The sural nerve passes between the two heads and should...
be preserved if at all possible during dissection. More proximal dissection toward the origin allows a greater arc of rotation, but great care has to be taken not to damage the sural artery inflow. The lateral head requires early identification of the common peroneal nerve beneath the deep fascia of the upper calf, below the neck of the fibula. The transposed muscle has to be passed superficially to protect the nerve during transposition, but its arc of rotation can be lengthened by tunneling it beneath the carefully dissected nerve.

**Personal Experience and Insights**

Proximal release is really important to achieve an adequate arc of rotation with these muscles. Scoring the deep fascial surface makes an enormous difference to the degree to which the diameter of the flap can be expanded. Use of the muscle to provide early coverage of exposed joint replacements is usually associated with successful salvage of the prosthesis. The procedure is exceptionally reliable, and the flap is robust.

**Recommendations**

**Planning**

When either of these muscle flaps is planned, a portion of the insertion into the Achilles tendon should always be harvested to provide a tendinous suture fixation point to hold the flap in its new position. Intramuscular sutures have a tendency to tear through if placed under tension. The anatomy of the sural nerve and common peroneal nerve should be borne in mind at all times.

**Technique**

The medial head is most easily accessed through a curvilinear incision extending from the inferomedial aspect of the knee wound down the medial side of the medial head toward the ankle. Division of the deep fascia provides easy access to the superficial surface of the muscle belly, and most of this dissection can be carried out with blunt digital dissection. Harvesting of the distal muscle belly should incorporate 2 to 3 cm of partial-thickness insertion into the Achilles tendon, allowing a strong fibrous tip to the flap for suture fixation proximally. On its deep surface, some cautery dissection is necessary, and deep perforators must be controlled with Ligaclip or surgical clips to prevent hematoma formation. I usually place drains at the donor site.

The flap should be dissected proximally as far as necessary to allow an adequate arc of rotation. The deep surface has a fascial component that can be scored or even excised to allow greater expansion of the surface area of the flap, particularly transversely. This simple maneuver greatly facilitates wound coverage.

Once the flap has been transposed into the defect, it is helpful to fix the distal tendinous insertion of the muscle beneath the supramedial wound edge using percutaneous nylon pull-out sutures. Skin grafting is then performed once the periphery of the flap has been inset with absorbable subcutaneous sutures.

The knee must be splinted with a very well-padded dressing incorporating an anterior plaster splint with a maximum of 15 degrees of flexion. Although the limb can be placed in full extension, this becomes uncomfortable within a few days after surgery. When using a lateral gastrocnemius, I always identify and dissect the common peroneal nerve, placing a silicone vessel tape around the nerve to maintain its identify during dissection. If a short arc of rotation is required, the flap can simply be passed over the dissected nerve, but if a longer arc is required, one can carefully pass the muscle beneath the nerve pulling it up over the fibula head. The muscle is then left under no tension, lying in relation to the fibula neck.
Postoperative Care
The key elements in managing these patients postoperatively is to prevent any significant motion of the knee while the flap is adhering to its new location. Although this is not as critical in covering proximal tibial defects, it is vital to splint the knee in only 10 to 15 degrees of extension for several weeks after surgery when knee coverage has been performed. I generally do not allow anything beyond 15 degrees of flexion for a month after surgery. This includes patients who have had an arthroplasty. Elevation is also important, as with any lower extremity coverage procedure. Gentle compression bandaging should be performed from the toes to above the knee to reduce postoperative edema. In high-risk patients, DVT prophylaxis should be instituted.

Take-Away Message
The gastrocnemius flaps are the most useful procedures available for knee and proximal tibial coverage. They are exceptionally reliable and are simple to perform, provided one takes care to protect the common peroneal nerve when performing the lateral flap.

Bibliography With Key Annotations

Clinical Series

The authors reviewed their extensive experience with the medial and lateral gastrocnemius muscle for lower leg reconstruction. Over a 5-year period, 21 medial and 13 lateral gastrocnemius muscle flaps were transferred. Based on their study and available reports on technical modifications and use of this muscle, they made seven recommendations: (1) isolate the vascular pedicle and divide the muscle origin for increased flap arc of rotation, (2) score or excise investing muscle fascia (epimysium) to increase muscle length and malleability, (3) split the muscle flap when necessary to provide coverage and fill bone defects simultaneously, (4) transpose both gastrocnemius muscles when required for defects, (5) pass the muscle directly through bone to fill certain defects, (6) use a V-Y advancement technique for distal leg defects, and (7) use a vertical (stocking-seam) incision for muscle exposure for flap elevation.


This is an excellent review of the dimensions, anatomy, and technique of elevation for medial and lateral gastrocnemius myocutaneous flaps. The authors noted that in young patients a muscle portion of the medial gastrocnemius myocutaneous flap was returned to the donor site and reattached to both Achilles tendon and the lateral gastrocnemius muscle after successful wound coverage.


In this early report of the use of the gastrocnemius myocutaneous flap the authors describe their anatomic dissections of 20 cadavers that established the blood supply to each head of the gastrocnemius through a large branch of the popliteal artery. They detail their operative technique and clinical experience in six patients. The reconstruction was successful in all patients. The authors reported that there were no gait abnormalities in their patients following the harvesting of one head of the gastrocnemius.


Plateau fractures of the tibia may be associated with vascular injury to the popliteal artery. Failure to recognize this vascular injury or late recognition with delayed vascular reconstruction results in amputation. The authors noted that the sural vessels to the gastrocnemius muscle are located proximal to the site of anterior occlusion of a popliteal artery and are generally viable despite lower leg ischemic
necrosis or compartment syndrome. In two patients salvage of the knee was accomplished using the gastrocnemius myocutaneous flap for coverage of the proximal tibia. Both patients achieved a functional below-knee amputation stump.


Ninety-five percent of primary bone sarcomas of the knee have extra osseous or soft tissue components. The defect after en bloc tumor resection results in lack of soft tissue for prosthetic coverage. The authors reported successful gastrocnemius flap transposition in 9 of 11 patients who underwent limb-sparing surgery. The choice of gastrocnemius muscle depends on which quadriceps muscle is resected (vastus medialis, use medial gastrocnemius; vastus lateralis, use lateral gastrocnemius muscle). Final determination of flap requirements is made after insertion of the prosthesis. Hamstring transfers are usually required to reconstruct the ipsilateral quadriceps mechanism. In this study seven primary and four secondary gastrocnemius transposition flaps were performed (eight medial and three lateral). Nine of 10 extremities were salvaged.


This early article advocated the use of the local gastrocnemius myocutaneous flap for coverage of defects traditionally treated with cross-leg flaps. The authors reviewed the vascular territory of the medial and lateral gastrocnemius myocutaneous flap. The extension of the skin island beyond the distal muscle belly was noted as a means to increase flap arc of rotation. Deep fascia was included with the skin island when it extended distal to the muscle belly. The authors reported successful use of this flap in 26 patients for coverage of defects in the distal thigh, knee, and proximal leg.


In this landmark article, the authors reviewed the application of muscle flaps to date and described the anatomy and arc of rotation of the medial head of the gastrocnemius, lateral head of the gastrocnemius, soleus, flexor digitorum longus, extensor hallucis longus, and abductor hallucis. They also described the vascular supply and point of rotation of each muscle. They further demonstrated the usefulness of muscle flaps for various reconstructive purposes, including repair of poorly vascularized defects of the lower leg, padding of bony prominences, repair of the thoracic wall, protection of large vessels, filling the empty orbit, filling the retroperitoneal cavity, controlling urinary incontinence, aiding in wound closure, contour restoration, and closure of vestiourethral fistulas. The authors noted that no vessels enter the medial belly of the gastrocnemius muscle, which is supplied solely by a large branch from the popliteal artery entering the muscle in the popliteal fossa. They reported good results in closing an open knee in a patient with an artificial knee joint. They noted that the lateral head of the gastrocnemius is smaller and shorter than the medial head and proximally is closely related to the peroneal nerve. One single branch of the popliteal artery supplies the muscle, entering high up in the midline where the heads of the gastrocnemius meet. The authors used the lateral head in three patients to close the knee joint, with successful results.

Flap Modifications


The authors described extending the vertically oriented skin island of the medial gastrocnemius myocutaneous flap distally from the traditional 5 cm above the medial malleolus to 2 cm. They also increased the width of the skin island 2 cm lateral to the posterior midline. After release of the fibers of muscle origin from the medial condyle of the tibia, they advanced the flap 5 to 6 cm inferiorly for coverage of distal third defects. In an excellent discussion of this paper, Morain noted that the posterior lateral extension of the skin island allows inclusion of the medial superficial sural artery, which may explain survival of this extended medial gastrocnemius myocutaneous flap.

An overview of the basic anatomy of the variations of the sural arteries and superficial sural arteries is presented. This is a good reference for an extensive discussion of more traditional fasciocutaneous flaps based on these vessels.


Medial and lateral gastrocnemius flaps are large flaps that can be taken in the lower extremity with no delay. They have a wide arc of rotation from above the patella in the thigh to the upper portion of the lower tibia. Both flaps can be taken simultaneously. They can cover extremely large defects of the anterior leg or knee. The use of these flaps with their ready availability, excellent blood supply, and wide range of coverage has tremendously facilitated immediate correction of severe injuries of the knee and lower leg.


This detailed cadaver study of the location of major perforators from either head of the gastrocnemius muscle pinpointed their variation using planar coordinates. In every leg, at least one major perforator emanated from the medial head. In most cases, this perforator originated from the medial sural artery. Occasionally, no major perforator could be found arising through the lateral head.


Under special circumstances, a chimeric form of combined flap can be advantageous. The formation of such a combination should be possible with any muscle perforator flap and its underlying muscle as a branch-based form of chimeric flap. In two patients with knee infections, this concept facilitated the use of local flaps only to simultaneously allow deep obliteration within the knee joint with the muscle portion while providing tension-free skin closure. Specifically, a chimeric gastrocnemius muscle and sural artery perforator flap, the latter based on either the medial or lateral sural source vessels, provided this reasonable solution. This is yet another new example of branch-based chimeric flaps, where the cutaneous component is a muscle perforator flap.


The universal adoption of muscle perforator flaps has been hampered by a lack of uniformity that would ensure the reliable harvest of the requisite vascular pedicle. Anatomic anomalies of their vascular supply are the anticipated norm, creating a conundrum, because retention of an adequate circulation is imperative to ensure the expected flap viability. Despite better preoperative assessment of the blood supply of muscle perforator flaps, including color duplex ultrasound, CT angiography, and MR angiography, Doppler ultrasonography remains the most convenient, inexpensive, and readily available method for evaluating a potential donor site.


The authors retrospectively reviewed the role of both muscle and fascia flaps in lower extremity injuries from a two-decade experience. Soft tissue deficits requiring some form of vascularized flap occurred in 160 limbs in 155 patients. The frequency of use of flap types, specific complications and benefits, effect of timing of wound closure, and rate of limb salvage were compared.


The medial sural artery perforator flap is a relatively thin cutaneous flap that can be most easily accessed if the patient can be placed in a prone position. This is an “ideal” flap if the recipient defect is in the posterior aspect of the body.

The authors described elevation of the medial gastrocnemius muscle as a free flap for coverage of proximal anterior leg defects. Since the muscle’s arc of rotation as a standard transposition flap was inadequate for complete defect coverage, the pedicle length was extended with use of lesser saphenous vein interposition grafts to revascularize the muscle flap. With this technique, the entire surface of the medial gastrocnemius muscle was successfully used for defect coverage.


The authors described medial and lateral gastrocnemius myocutaneous flaps. Their usefulness as direct flaps without a delay in reconstruction of the lower extremity was discussed. The authors noted that this flap had supplanted the cross-leg flap for most of their reconstructions in the lower extremity.


The authors enumerated variations of the origin and number of the sural arteries. This is one explanation of how collateral vessels sustain the muscle, even if a major sural source pedicle has been sacrificed.


A clear understanding of the vascular anatomy of an individual perforator relative to its vascular territory and flow characteristics is essential for both flap design and harvest. The authors investigated the three-dimensional and four-dimensional arterial vascular territory of a single perforator, called a “perforasome,” in major clinically relevant areas of the body. A vascular anatomy study was performed using 40 fresh cadavers. A total of 217 flaps and arterial perforasomes were studied. Dissection of all perforators was performed under loupe magnification. Perforator flaps on the anterior trunk, posterior trunk, and extremities were studied. Flaps underwent both static (three-dimensional) and dynamic (four-dimensional) computed tomographic angiography to better assess vascular anatomy, flow characteristics, and the contribution of both the subdermal plexus and fascia to flap perfusion. The perfusion and vascular territory of perforators is highly complex and variable. Each perforasome is linked with adjacent perforasomes by means of two main mechanisms that include both direct and indirect linking vessels. The vascular axis follows the axiality of linking vessels. Mass vascularity of a perforator found adjacent to an articulation is directed away from that same articulation, whereas perforators found at a midpoint between two articulations, or midpoint in the trunk, have a multidirectional flow distribution.


The prototypical conjoint or so-called chimeric free flap heretofore has been composed of several large independent flaps, each supplied by a separate major branch, that ultimately arise from a common source vessel. The perforator-based type of chimeric flap is a relatively new concept, usually involving multiple muscle perforator flaps each based on a solitary myocutaneous perforator, but still arising from the same “mother” vessel. This principle of split cutaneous perforator flaps has now been successfully adapted to the medial sural medial gastrocnemius perforator free flap on two separate occasions. As a chimeric flap, there was greater flexibility in insetting, and overall flap width may be larger but still narrow enough to allow primary donor site closure; and yet, by definition, only a single recipient site was needed for any microanastomoses. This is further proof that the perforator-based chimeric free flap may be an option for any muscle perforator flap donor site, so that potential donor territories for conjoint flaps have become virtually unlimited.


Various reconstructive choices are available for the coverage of soft tissue defects around the knee joint or upper third of the lower leg, depending on the location, size, and depth of the defect. The authors have found the medial sural artery perforator island flap a useful method for reconstruction of the upper
third of the lower leg and knee. From January 2003 to November 2005, medial sural perforator island flaps were used on six patients, five were men and one was a woman. The largest flap obtained was 16 by 7 cm. In three cases, defects were located on the upper third of the lower leg and in the other cases, on the knee. Four patients had bone exposed, and two had a postburn contracture. All six flaps survived completely, without even minor complications. Postoperative follow-up of the patients ranged from 2 to 33 months. The main advantages of the medial sural perforator island flap are a constant location and reliable blood supply without sacrifice of any main source artery and underlying muscle. This procedure is a valuable extension of local flap for defect coverage with minimal functional deficit of donor site and good aesthetic result on the defect and is a useful method for reconstruction of the upper third of the lower leg and knee.


Before the term perforator flap was used, these pioneers sought new free flap donor sites based only on cutaneous perforators. A calf skin flap raised on a single gastrocnemius myocutaneous perforator was followed via an intramuscular dissection back to the respective sural artery pedicle. This flap could rightfully be called the first sural artery perforator flap.


The arterial communication between the gastrocnemius muscle heads through their lowest anastomotic arteriole bundle alone was examined in specimens from 14 fresh cadavers. In three specimens, the larger vessels in close vicinity to the lowest vessels were preserved as well. Distinct communication between the arterial networks of the heads was demonstrated in all cases after injecting dyes through both sural arteries or into the lateral sural artery and the lowest anastomotic arteriole in 11 and three specimens, respectively. Therefore it seems that one head can be adequately supplied from the contralateral one through their lowest anastomotic arterioles; nevertheless, the location of this vessel varies significantly and cannot be detected preoperatively. Measurements demonstrated that although this vessel is not found at a constant level, it is invariably detected in the lower third of the medial gastrocnemius head’s length and, in 93% of cases, in the lower fourth. Thus rough preoperative planning becomes feasible. Given that the venous communication between the heads has been documented as well, the authors think that an inferiorly based flap of the medial gastrocnemius head for defects of the middle third of the tibia might be both reliable and applicable; however, for reasons of safety, the muscle heads should remain attached along their lower third.


The authors presented four clinical cases, their initial experience with a fasciocutaneous free flap unit. The territory of this flap incorporates the skin, fat, and fascia of the posterior calf region. Its design is based on the principle of the fasciocutaneous flap. Anatomic studies confirm that the blood supply to this flap is derived from a descending subfascial branch of the popliteal artery. The flap is well endowed with cutaneous sensory nerves, making it a potential neurosensory free flap. The technique of flap design and elevation was presented and potential advantages and disadvantages of this flap were discussed.


Sometimes the myocutaneous perforators to the calf are inadequate to permit use of a muscle perforator flap. An inverse relationship with cutaneous (direct) vessels exists. If the latter are dominant, more traditional calf fasciocutaneous flaps have to be used.
ANATOMIC LANDMARKS

**Landmarks**
Middle and upper third of the anterolateral surface of the leg.

**Size**
Skin: $10 \times 20$ cm, muscle: $4 \times 25$ cm; nerve: $25$ cm.

**Origin**
Lateral condyle of the tibia, upper lateral surface of the tibia, and interosseus membrane.

**Insertion**
Medial cuneiform and base of first metatarsal.

**Function**
Critical muscle responsible for dorsiflexion and inversion of the foot.

**Composition**
Cutaneous, fasciocutaneous, muscle, vascularized nerve.

**Flap Type**
Type IV, muscle.

**Dominant Pedicles**
Anterior tibial artery; superolateral peroneal artery; inferolateral peroneal artery.

**Nerve Supply**
*Motor*: Branches of the deep peroneal nerve. *Sensory*: Superficial peroneal nerve.
Section 13E

LEG

Anterior Tibial Flap

CLINICAL APPLICATIONS

Regional Use
- Middle third of leg
- Lower third of leg
- Knee
- Foot
- Heel

Distant Use
- Head and neck
- Upper extremity
- Lower extremity

Specialized Use
- Free vascularized nerve graft
ANATOMY OF THE ANTERIOR TIBIAL FLAP

A

Tibialis anterior muscle reflected to demonstrate location of anterior tibial artery

B

Anatomy of anterior tibial artery

C

Neurovascular anatomy of anterior tibial axis

D

Cross-sectional diagram

Fig. 13E-1

Dominant pedicles: Anterior tibial artery; superolateral peroneal artery; inferolateral peroneal artery
ANATOMY

Landmarks  The skin of this flap occupies the middle and upper third of the leg in the anterior lateral aspect. The muscle is the largest muscle of the anterior compartment.

Composition  Flap can be used as a muscle-only flap in turnover and also can be used as a cutaneous or fasciocutaneous flap based off of perforators of the anterior tibial artery. The peroneal nerve also runs with the vessel as it descends in the leg, providing an opportunity for a long, vascularized nerve graft.

Size  Skin: 10 × 20 cm; muscle: 4 × 25 cm; nerve: 25 cm.

Origin  Lateral condyle of the tibia, upper lateral surface of the tibia, and interosseus membrane.

Insertion  Medial cuneiform and base of the first metatarsal.

Function  Critical muscle responsible for dorsiflexion and inversion of the foot.

Arterial Anatomy (Type IV, Muscle)

Dominant Pedicle  *Anterior tibial artery*

Regional Source  Popliteal artery.

Length  1 to 2 cm.

Diameter  6 mm.

Location  Lateral deep aspect of the muscle.

Dominant Pedicle  *Superolateral peroneal artery (SLPA)*

Regional Source  Anterior tibial artery.

Length  6 to 12 cm.

Diameter  2 mm.

Location  Arises from the tibial artery 8 cm below the head of the fibula and 25 cm above the lateral malleolus. Courses on the interosseous membrane to the anterior intermuscular septum. It gives off muscular branches to the peroneus longus and extensor digitorum longus muscles and provides a superficial peroneal nerve accessory artery that vascularizes the superficial peroneal nerve distally.

Dominant Pedicle  *Inferolateral peroneal artery*

Regional Source  Anterior tibial artery.

Length  5 cm.

Diameter  1.5 mm.

Location  Originates from the anterior tibial artery 17 cm below the head of the fibula and 17 cm above the lateral malleolus. It gives off muscular branches to the extensor digitorum longus and the peroneus brevis muscles and courses through the anterior intermuscular septum, supplying a branch to the superficial peroneal nerve accessory artery.

Venous Anatomy

Accompanying the tibial vessel are a paired comitans veins. Both of the superolateral and inferolateral peroneal arteries have accompanying comitans veins. The anterior tibial venae comitantes join the venae comitantes of the posterior tibial artery to form the popliteal vein, which is a single vein.

Nerve Supply

Motor  Branches of the deep peroneal nerve.

Sensory  Superficial peroneal nerve.
Vascular Anatomy of the Anterior Tibial Flap

Fig. 13E-2

Dominant pedicles: Superolateral peroneal artery ($D_2$); inferolateral peroneal artery ($D_3$)

Major segmental pedicles: Eight to twelve arterial muscular branches (short white arrows)
FLAP HARVEST

Design and Markings

For the skin perforator flap, a line is drawn from the anterior edge of the head of the fibula to the anterior edge of the lateral malleolus. If the proximal rotation of the flap is desired, such as for knee coverage, the design is based off the inferolateral peroneal perforator and therefore the skin island is centered between the middle and lower thirds of the leg. If a more distal rotation is desired, the skin paddle is centered on the superolateral peroneal perforating vessels, centered at the junction of the upper and middle thirds of the leg.

Patient Positioning

Patient positioning is supine with a tourniquet on the thigh.
GUIDE TO FLAP DISSECTION
A posterior incision is made first over the peroneal muscles down through skin and fascia. If desired, the flap can be elevated in a suprafascial plane. Dissection proceeds from posterior to anterior with identification of the intermuscular septum, which separates the anterior from the lateral compartment of the leg.

Fig. 13E-4 A, A posterior incision is first made over the peroneal muscle through the skin and crural fascia. Dissection is continued in its subfascial plane from a posterior to an anterior direction. Dissection continues to the anterior intermuscular septum.
Perforating vessels and their comitantes are located in this intermuscular septum. Next the superior margin is incised and elevated, further identifying the perforating vessels and their comitantes within the intermuscular septum.

**Fig. 13E-4 B**, The SLPA and its venae comitantes are identified in the intermuscular septum.

At this level, the superficial peroneal nerve can be visualized, located just lateral to the vascular pedicle.

**Fig. 13E-4 C**, The superior margin of the flap is elevated, and the SLPA and its venae comitantes are identified and traced within the intermuscular septum to their origin from the anterior tibial artery and its venae comitantes. Note that the superficial peroneal nerve at this deep location is lateral to the vascular pedicle within the septum.
The anterior flap margin is then incised and again carried in the subfascial or suprafascial plane toward the intermuscular septum.

Fig. 13E-4  D, An anterior flap incision is made and carried posteriorly to the intermuscular septum, further isolating the flap on its vascular pedicle.

The flap is now isolated on its vascular pedicle. Muscle branches to lateral and anterior compartment muscles are ligated. By releasing the origin of the extensor muscles from the fibula and interosseous membrane and retracting these muscles medially, exposure of the anterior tibial artery and vena comitans is facilitated. The deep peroneal nerve can also be seen between the extensor muscles and the anterior tibial muscle.

Fig. 13E-4  E, The extensor muscles are retracted medially, and the flap vessels are traced more proximally to their origin from the anterior tibial artery and its venae comitantes. Muscle branches are ligated.
Finally, the inferior flap margin is elevated, completing the elevation of the flap. Decisions are made at this point as to which perforating vessels are included with the flap. If the superolateral peroneal artery is diminutive, segmental perforators from the anterior tibialis muscle can be included. This requires the anterior tibial to be sacrificed, because it is the feeding vessel to these perforators.

Fig. 13E-4  F, If the SLPA is thought to be inadequate in size and diameter, additional fasciocutaneous and myocutaneous branches coursing through the tibialis anterior muscle may be included. This would by necessity make the anterior tibial artery and its vena comitans a donor pedicle, sacrificing major limb vessels.

Division of the anterior tibial artery and its comitans superiorly allows a posterior flap to be rotated. Division of these vessels inferiorly allows the island flap to be rotated superiorly.

Fig. 13E-4  G, The fasciocutaneous flap is isolated on the proximal anterior tibial artery and its vena comitans and is observed for continuous perfusion.
FLAP VARIANTS

- Reverse flap
- Muscle flap
- Vascularized nerve graft

Reverse Flap
The lower third of the leg is hard to reconstruct with local flap but the reverse anterior tibial flap is an option, although sacrifice of the anterior tibial artery and its blood supply to the distal leg is required. The flap design is moved superiority to the junction of the upper and middle thirds of the leg and both the superolateral and inferolateral peroneal branches of the anterior tibial artery are included with the flap. The anterior tibial artery is divided superiorly, allowing rotation distally.

Fig. 13E-5
Muscle Flap
The anterior tibial muscle is not an expendable muscle and is responsible for dorsal flexion and inversion of the foot. It can, however, be used as an advancement for middle and third wounds of the leg. Due to the segmental nature of the muscle, blood supply, division, and rotation of the flap is not recommended. The freeing up of the muscle and splitting the muscle can allow advancement to cover exposed areas of the tibia, as a local advancement, maintaining the innervation and function of the muscle.

Flap elevation and advancement for medial longitudinal split muscle flap

Flap elevation and advancement for lateral longitudinal split muscle flap

Fig. 13E-6
**Vascularized Nerve Graft**

As the anterior tibial artery supplies the deep peroneal nerve by contributing to the superficial peroneal nerve accessory artery, this allows harvest of nerve extending from the proximal third of the leg to the distal foot with a maximum length of up to 25 cm. This can then be transferred as a vascularized nerve graft. A small skin paddle can be harvested with this nerve graft based on either the inferolateral or superolateral peroneal vessels to monitor the vascularized nerve graft.

![Anterior tibial vascular system and its relationship to the deep peroneal nerve](image)

**Fig. 13E-7**

A, Anterior tibial vascular system and its relationship to the deep peroneal nerve. B, Clinical example of a harvested deep peroneal nerve graft with a short segment of the pedicle vessel and a small anterior tibial artery perforator (ATAP) monitor flap.
ARC OF ROTATION
Proximally Based Perforator Flap
The flap can be rotated to reach the upper third of the leg, knee, and popliteal fossa.

Arc of rotation to knee

Fig. 13E-8

Distally Based Perforator Flap
The flap can be rotated to reach the ankle, foot, and heel.

Arc of rotation to foot

Fig. 13E-9
Muscle Flap
Advancement of the muscle after release is reliable only for a few centimeters. The muscle is often in the “zone of injury” in cases of trauma and is not usable for local advancement.

FLAP TRANSFER
The proximally based flap can be transferred directly or via a subcutaneous tunnel.

Reverse Flap
The reverse flap can be transferred either directly or through subcutaneous tunnel. The area over the ankle is quite thin and may not be conducive to creation of the tunnel and passage of the flap. In these cases, direct passage of the flap through an incision is preferred. At times, skin grafting of the pedicle is required as a safeguard against compression and kinking with closure.

Muscle
Transfer of the muscle is through direct advancement.

FLAP INSET
It is essential to inset the flap without tension. Controlling motion of the donor site at the knee and ankle joint is critical to permit uncomplicated healing. Inset of the muscle advancement is performed with a series of sutures to the muscle or fascia beyond the bony defect.

DONOR SITE CLOSURE
Skin harvested in this area often requires a skin graft for closure of these defects. Muscle advancement can often be closed primarily by undermining of the surrounding skin and the subcutaneous plane.
**CLINICAL APPLICATIONS**

This patient sustained a degloving wound of the proximal right leg as a result of a motor vehicle accident.

**Fig. 13E-10**  
A, Degloving injury at presentation.  
B, The wound was debrided, including the shredded fascia of the tibialis anterior muscle (upper arrow). The tibia stripped of periosteum was exposed (lower arrow), with insufficient skin remaining for primary closure.  
C, The exposed tibialis anterior muscle (arrow) was minimally split sagittally (dashed line) to allow simple advancement to cover the bone.  
D, The healed right leg is seen after skin grafting of the tibialis anterior muscle and the residual defect. (Case courtesy Geoffrey G. Hallock, MD.)
This man presented with a posterior hindfoot pressure sore. An anterior tibial flap reconstruction was planned.

**Fig. 13E-11**  
A, Heel defect at presentation. B, Design of the anterior tibial skin flap based on proximal perforators, with the course of the anterior tibial artery marked. C, The elevated flap was attached to the distal anterior tibial vascular pedicle. D, The distally based anterior tibial artery flap was turned to reach the heel defect. E, Venous congestion developed after flap insetting, a notorious problem with this flap. F, Nevertheless, enough flap survived to allow ultimate healing. G, A detrimental factor with the use of the anterior tibial artery flap is the unaesthetic skin grafted donor site. (Case courtesy Geoffrey G. Hallock, MD.)
This polytrauma patient had an exposed plate after open reduction of a lateral malleolar fracture.

Fig. 13E-12  A, Exposed plate (arrow) after open reduction surgery. B, A proximally based peninsular flap (arrow) was raised over the anterior lower leg, carefully dissected to prevent exposure of the underlying tendons. C, Although the flap adequately covered the plate, a large donor site defect (arrow) required skin grafting. D, This relatively simple maneuver in this moribund patient provided adequate coverage for what later proved to be a useful limb salvage. (Case courtesy Geoffrey G. Hallock, MD.)
Pearls and Pitfalls

- Other than local rotation based on the perforators only, the anterior tibial artery flap is rarely used, since it requires sacrifice of a major vessel of the leg. If division of the anterior tibial artery is anticipated, a preoperative arteriogram is recommended to ensure proper vascularization of the leg.
- The flap can be elevated under tourniquet control, minimizing blood loss and improving visualization for dissection.
- A long pedicle with a large external diameter can be obtained. There is some variability to the anatomy in this area. A Doppler examination should confirm the perforator location before the incision is made.
- A skin grafted donor site has a poor cosmetic appearance. One must be aware of superficial peroneal nerve injury during the dissection and preserve the nerve.
- If the inferolateral perineal artery is present, the anterior tibial flap is quite useful for treatment and coverage in the distal third of the leg, especially the malleolar and heel area.
- Other donor sites are much more favorable for free tissue transfer, and free flaps based off the anterior tibial vessel are rarely performed.

EXPERT COMMENTARY
Geoffrey G. Hallock

Indications
The anterior tibial artery originates from the popliteal artery at the lower border of the popliteus muscle behind the upper tibia, then circumnavigates the tibia to pass above the upper margin of the interosseous membrane to enter the anterior compartment of the leg, where it then courses distally to terminate as the dorsalis pedis artery at about the midpoint of the medial and lateral malleoli at the ankle. During this pathway, numerous branches supply contiguous muscles, bone, nerves, and overlying skin, which can then in turn be used as various tissue flaps.

Taylor et al showed that a recurrent genicular branch supplies the proximal fibular epiphysis and shaft, which is an advantageous vascularized bone graft donor site in the rare situation if future bone growth is essential. Breidenbach and Terzis, among others, described the capability of proximal anterior tibial perforators to allow a vascularized superficial peroneal nerve transfer, whereas Koshima et al and Zhang et al used the deep peroneal nerve as a vascularized graft, although that requires sacrifice of the anterior tibial artery that must remain attached.

Advantages and Limitations
Muscle Flap
From a pragmatic standpoint, the anterior tibial artery as a source vessel has very limited applications, and those are restricted to its supply of anterior compartment muscles and some cutaneous flaps. The most versatile muscle flap is the tibialis anterior muscle, which can be valuable for covering small proximal and midtibia bony defects (see Fig. 13E-9). As already mentioned, this is a type IV muscle according to the stratification of Mathes and Nahai, since it is supplied segmentally by multiple branches of the anterior tibial artery. It is also
nonexpendable: it is essential for dorsiflexion and inversion of the foot. Longitudinal splitting of this muscle along its lateral border toward its central intrinsic tendon will allow it to serve as a turnover flap for local coverage, while preserving its circulation and tendon attachments to permit function preservation.

**Cutaneous Flap**

Cutaneous flaps incorporating the skin of the anterior and anterolateral leg rely primarily on septocutaneous perforators. Schaverien and Saint-Cyr showed through cadaver studies that although anterior tibial artery perforators are more numerous than posterior tibial and peroneal artery perforators, these tend to be much smaller, which makes them less useful. They also tend to be found in proximal and distal clusters, with the former having the largest caliber, possibly sufficient to supply propeller or rotation skin flaps that can reach the knee and patella. Unfortunately, these perforators have numerous anatomic variations, not only in their very existence, but also in size, location, and the septum of origin.

From a historical perspective, these same proximal perforators were described some 25 years ago to allow the elevation of a reverse or distally based anterior tibial flap whereby this proximal skin territory could reach foot and ankle defects and thus avoid the need for a microsurgical tissue transfer (see Fig. 13E-10). However, this maneuver may require sacrifice of a major limb artery, depending on the presence of otherwise adequate collateral circulation to the foot. Continuity of the plantar arch is required to ensure reverse inflow, and venous congestion is not uncommon. These detrimental factors have ensured that the many other alternatives now available have made this option moot today.

Discrete distal perforators of the anterior tibial artery at the level of the extensor retinaculum have been described to supply an adipofascial flap from the foot for distal leg coverage. More practical, however, is the presence of a confluence of suprafascial vessels arising from all three source vessels to the foot, which provides a network of “fascial feeders” so that proximally based peninsular flaps with length-to-width ratios of up to 3:1 can be raised here without the need to identify a specific perforator.

Since flow is orthograde, there is no risk of venous congestion. This is a local flap option that can be raised quickly, with the deep fascia usually kept with the flap to preserve the suprafascial and subfascial plexus (see Fig. 13E-11). Small ankle defects can thus be readily covered. Because of the lack of skin redundancy at this level, often the donor site must be skin grafted, so the surgeon must exercise care in the design of these flaps so that bone or tendon exposure is avoided.

**Take-Away Messages**

Reliable workhorse flaps based on the anterior tibial artery include the tibialis anterior muscle flap, which is useful for coverage of small adjacent proximal or midleg defects. Its diminutive distally based perforators need not be specifically identified, yet they can supply small local peninsular skin flaps for ankle coverage, avoiding the need for a more complex microsurgical tissue transfer or the risk of a distally based regional flap.

**References**


*Continued*

**Bibliography With Key Annotations**


*Ian Taylor introduced the angiosome concept, separating the body into distinct three-dimensional blocks of tissue fed by source arteries. Understanding the angiosomes of the foot and ankle and the interaction among their source arteries is clinically useful in surgery of the foot and ankle, especially in the presence of peripheral vascular disease. In 50 cadaver dissections of the lower extremity, arteries were injected with methylmethacrylate in different colors and were dissected. Preoperatively, each reconstructive patient’s vascular anatomy was routinely analyzed using a Doppler instrument and the results were evaluated. There are six angiosomes of the foot and ankle originating from the three main arteries and their branches to the foot and ankle. The three branches of the posterior tibial artery each supply distinct portions of the plantar foot. The two branches of the peroneal artery supply the...*
anterolateral portion of the ankle and rear foot. The anterior tibial artery supplies the anterior ankle, and its continuation, the dorsalis pedis artery, supplies the dorsum of the foot. Blood flow to the foot and ankle is redundant, because the three major arteries feeding the foot have multiple arterial-arterial connections. By selectively performing a Doppler examination of these connections, it is possible to quickly map the existing vascular tree and the direction of flow.


The foot offers numerous useful options for hand reconstruction. Hallux transfer, dorsalis pedis flap, second toe transfers, and toe joint transfers offer good functional results in reconstructed hands. However, when the donor site is repaied with skin grafts, delayed wound healing, scarring, and contractures often result. Poor cosmesis of the donor site and altered gait are the main drawbacks of the procedures.

The authors proposed a new concept of primary reconstruction of the donor foot using a reverse-flow anterior tibial flap from the same leg. Two flaps are raised from the same anterior tibial vessel system in continuity as a distal free flap for hand reconstruction and as a proximal reverse-flow pedicled flap to resurface the donor defect. This technique allows good flap reconstruction of the foot donor site, reducing morbidity and limiting the operation to the same limb. The authors reported their experience with 33 cases. There were no flap failures. Primary wound healing was achieved in the foot donor site, with acceptable cosmesis and satisfactory function.


Combined flaps serve a unique niche when significant or multidimensional defects need to be corrected. Perforator flaps have become a new alternative for achieving this same objective. As this latter genre evolves, it is reasonable to also expect the development of combined perforator flaps. Combined flaps based on perforators, as with any other combined flaps, can be classified into two major subtypes. These in turn may be further subdivided into various subcategories according to their inherent pattern of circulation and whether this is indigenous or naturally occurring, or must be intentionally fabricated using microsurgical techniques. The two major subdivisions of combined perforator flaps are conjoined or chimeric perforator flaps. Conjoined perforator flaps incorporate “multiple perforasomes, each dependent due to a common physical junction, with each perforasome supplied by an independent perforator.” Chimeric perforator flaps consist of multiple cutaneous territories, involving “multiple perforasomes, each supplied by an independent perforator, and independent of any physical connection with other perforasomes except where the perforators are linked to a common vascular source.”


A true muscle perforator flap is distinguished by the requisite intramuscular dissection of its myocutaneous perforator to capture the same myocutaneous territory but with total exclusion of the muscle, and thereby results in minimal functional impairment. Adhering to this definition, several lower extremity donor sites are now available, each with specific attributes especially useful for consideration in the treatment of lower extremity defects. In the author’s experience over the past two decades, 20 lower extremity muscle perforator flaps using multiple donor sites proved advantageous for lower extremity coverage problems as either a local pedicled flap or as a microsurgical tissue transfer. Significant complications occurred in 30% of flaps (6 of 20) in that further intervention was required. Venous insufficiency and bulkiness were found to be the major inherent shortcomings. However, giant flaps, lengthy and large-caliber vascular pedicles, and the possibility for combined flaps were important assets. The choice of a lower extremity muscle perforator flap for lower extremity reconstruction limited the surgical intervention and morbidity to a single body region.


Free tissue transfer to the lower extremity has become a well-established reconstructive modality. The purpose of this study was to develop a “subunit” approach to patients undergoing free tissue transfer for foot and ankle wounds to help further define subunit-specific functional and aesthetic operative goals.
The authors presented a retrospective review of 161 patients who underwent free tissue transplantation for foot and ankle wounds over 10 years at a single institution. Endpoints included flap-related complications, secondary surgery, time to ambulation, flap stability, and limb salvage. The authors concluded that the use of free tissue transplantation for treatment of foot and ankle wounds is associated with a high rate of limb salvage. Although a variety of flaps may be used, the application of the subunit principle can assist surgeons in designing flaps that will address subunit-specific functional and aesthetic concerns.


The aim of lower extremity reconstruction has focused on early wound coverage and functional recovery but rarely aesthetics. Free muscle flaps provide durable coverage; however, they require skin graft coverage and result in muscle atrophy limiting future revisions. Perforator-based flap reconstructions can be easily elevated to allow both orthopedic and contouring procedures. The authors reviewed the role of secondary procedures in achieving improved functional and aesthetic results following perforator flap reconstruction of lower extremity defects. A retrospective review identified 70 patients treated from 2002 to 2009 with 73 free perforator flaps for coverage of lower extremity wounds. Seventy patients underwent reconstruction with a perforator flap: 65 with anterolateral thigh flaps and 5 with superficial circumflex iliac artery flaps. Nineteen of these patients underwent 32 refinement procedures of the reconstructed limb. Fifteen refinements were performed with suction-assisted lipectomy, 21 with complex tissue rearrangement, including sharp debulking, and 1 with tissue expanders. Twenty-seven of the 70 patients underwent 40 orthopedic-related secondary procedures in which the free flap was elevated. The most common reasons for the orthopedic interventions were tibial nonunion requiring bone grafting (17) and osteomyelitis (11). Limb salvage remains the primary goal of lower extremity reconstruction. Following convalescence and functional recovery, however, appearance becomes increasingly important with regard to quality of life. Initial flap selection with free perforator flaps, meticulous inset, and secondary refinements provide superior functional and aesthetic outcomes.


The use of perforator flaps has increased; they offer advantages such as sparing of the underlying muscle with resultant decreased donor-site morbidity and the possibility of improving the aesthetic outcome. Theoretically, a flap can be based on any perforator, whether free or pedicled, based on the perforasome theory. In this study, the principle of free-style perforator flaps was used to harvest pedicled flaps. The authors reported the cumulative experience with freestyle perforator flaps of two medical centers (Hôpital Maisonneuve-Rosemont and University of Texas Southwestern Medical Center). Fifty-three pedicled perforator flaps were performed on 49 patients for local reconstruction of a range of defects at various anatomic locations: head and neck, anterior trunk, posterior trunk, perineal/gluteal, lower limb, and upper limb. Complete flap survival was obtained in 48 of 53 flaps. Complications included three cases of partial flap necrosis and two total flap failures, the latter in high-risk patients. Complete primary closure of the donor site was possible in 37 cases, especially in the trunk. Twelve patients had partial primary closure complemented by skin grafting, three cases required complete skin grafting, and one donor site required another local flap for closure. Five clinical examples were given: anterior trunk, posterior trunk, cervical region, lower limb, and upper limb.


The aim of this study was to investigate in detail the distribution and characteristics of cutaneous perforators of the lateral aspect of the lower leg. Fifty-two fresh cadaver legs were dissected. The lateral lower leg was divided into five zones, and all cutaneous perforators were identified. Only perforators with a diameter greater than 0.5 mm were dissected further, and the type, location, course, length, and origin of those perforators were recorded. Three hundred two perforators were dissected. Two hundred twelve were septocutaneous (70.2%), 43 were septomyocutaneous (14.2%), and 47 were
myocutaneous (15.6%). The majority of perforators (78.1%) originated from the peroneal artery. The peroneal artery was the dominant source vessel in all except for the proximal zone. The tibial-peroneal trunk predominated in the proximal zone. High contribution of the posterior tibial artery was noticed in the distal zone. Higher percentages of perforators were recorded in the middle and midproximal zones (26.8% and 25.2%, respectively). Septocutaneous perforators were present in all five zones, with higher percentages in the middle and middistal zones. Septomyocutaneous and myocutaneous perforators were identified in all except for the distal zone.


Transfer of a vascularized fibular graft is the method of choice for reconstruction of defects of long bones. In particular, the vascularized fibula head graft is preferred for patients with bone defects of the upper limb involving the distal radius or the proximal humerus. The aim of this study was to analyze the operative results, complications, and postoperative function after vascularized fibula head graft transfer and the indications for this procedure. Vascularized fibula head graft transfers were performed in eight patients to reconstruct bone defects following resection of tumors of the upper limb. The primary site of the tumor was the proximal humerus in four patients and the distal radius in four patients. The postoperative course of the transferred bone was examined, and functional results were evaluated. All vascularized fibula head grafts were transferred successfully. During the follow-up period, absorption of the transferred fibula head was not observed. The mean overall functional rating of the reconstructed shoulder joint was 70%. The range of motion of the reconstructed wrist joint showed no specific patterns, and instability of the wrist joint was observed in only one case. The authors concluded that the vascularized fibula head graft transfer is a safe and reliable method for reconstructing the upper limb, especially for patients with a defect of the distal radius or the proximal humerus. This procedure is also useful for pediatric patients, in whom bone growth is expected after transplantation, and for salvage procedures after reconstructive materials of an artificial joint have failed.


Satisfactory reconstruction of skin defects over the lower leg remains a difficult problem. Various forms of coverage, including local rotation flaps, muscle flaps, and fascial and free flaps, have their specific indications and inherent disadvantages. The authors described a new axial skin flap based on perforating vessels in the territory of the anterior tibial artery. A series of 50 lower leg dissections was carried out in 25 fresh cadavers after latex injection into the femoral artery. Detailed studies of the cutaneous distribution of the anterior tibial artery showed that three main arteries perfuse the anterior lateral portion of the lower leg. The superior lateral peroneal artery and the inferior lateral peroneal artery interseptal cutaneous perforators arise at an average of 25.6 and 17.2 cm from the lateral malleolus, respectively. The superior lateral peroneal artery was present in 100% of the specimens, whereas the inferior lateral peroneal artery was present in 70% of the specimens. In their course, they give several muscular branches to the peroneus longus and brevis prior to perforating the fascia and arborizing in the subcutaneous tissues of the anterolateral portion of the leg. The average external diameter was 1.6 cm for the superior and 1.4 cm for the inferior lateral peroneal artery. The superficial peroneal nerve accessory artery is the third artery which contributes to the skin of the lower leg. It arises from the superior lateral peroneal artery in 30% of cases, from the inferior lateral peroneal artery in 40%, and from both in 30%. The artery runs along with the superficial peroneal nerve and gives several cutaneous perforators along its descending course. Several cutaneous axial flaps can be fashioned around this anatomy.


A vascular anatomy study was performed using 40 fresh cadavers. A total of 217 flaps and arterial perforasomes were studied. Dissection of all perforators was performed under loupe magnification. Perforator flaps on the anterior trunk, posterior trunk, and extremities were studied. Flaps underwent both static (three-dimensional) and dynamic (four-dimensional) CT angiography to better assess
vascular anatomy, flow characteristics, and the contribution of both the subdermal plexus and fascia to flap perfusion. The perfusion and vascular territory of perforators is highly complex and variable. Each perforasome is linked with adjacent perforasomes by means of two main mechanisms that include both direct and indirect linking vessels. Vascular axis follows the axiality of linking vessels. Mass vascularity of a perforator found adjacent to an articulation is directed away from that same articulation, whereas perforators found at a midpoint between two articulations, or midpoint in the trunk, have a multidirectional flow distribution.


Pedicled perforator flaps in the lower leg enable reconstruction of a variety of local defects without microvascular anastomoses and with minimal donor-site morbidity. This study determined the reliable locations of the lower leg perforators. Twenty lower limbs harvested from fresh cadavers were used. In 15 specimens, colored latex intraarterial injections were performed, followed by dissection in the suprafascial plane; perforators with a diameter greater than 0.5 mm were located with respect to a line between the tips of the medial and lateral malleoli. In five further specimens, intra-arterial injection of a barium sulfate/gelatin mixture was performed and computed tomographic scans were acquired. Cluster analysis was performed to determine the 5-cm intervals where perforators were most commonly encountered within each septum. Perforators were located in discrete intermuscular septa. Those arising from the anterior tibial artery were predominantly encountered within three septa, and those of the peroneal and posterior tibial arteries were found within discrete septa. Reliable perforators were found within three distinct 5 cm intervals: at 4 to 9 cm, 13 to 18 cm, and 21 to 26 cm from the intermalleolar line. The anterior tibial artery perforators clustered in the distal and proximal intervals, those of the peroneal artery in the middle interval, and those of the posterior tibial artery in all three intervals.


This anatomic study involved the meticulous dissection of three fresh cadaveric specimens to characterize the vascular supply of the nerves of the lower limb. The findings demonstrated that the nerves were supplied segmentally by source vessels, which were color-coded to match the corresponding angiosomes. The segments were then classified into five categories according to whether the nerves and source vessels were branched or unbranched, which has clinical relevance for harvesting of nerves for vascularized nerve transfers.


Technical advancements and increased experience with perforator flap techniques have allowed the harvest of flaps in a free-style manner. To perform free or local island pedicled flaps using the free-style concept, one requires mature skills in retrograde dissection of vascular pedicles and in using a hand-held Doppler device. To keep the technique safe, certain principles should be remembered and are detailed in this article. The free-style flap concept provides unparalleled freedom when choosing local or distant soft tissues for reconstructing a defect. Potential pitfalls during free-style flap harvest can be avoided if the presented principles are adhered to. Newer imaging modalities may prove useful for assessing vessels supplying any cutaneous territory.


The blood supply to the skin of the anterior leg was studied in 10 fresh cadavers. Particular attention was paid to the intermuscular septal blood vessels, which emerge in the deep between tibialis anterior and extensor hallucis longus and extensor digitorum longus muscles. With this anatomic knowledge, the reverse-pedicled anterior tibial fasciocutaneous flap was designed and transferred clinically to cover lower leg and foot defects in six patients. Three case reports were detailed. The factors that allow a distally based flap to be raised in the lower leg against the direction of venous valves were also described. The versatility of this new flap in the reconstruction of defects of the lower leg and foot was discussed.

Reconstruction of severe traumatic injuries of the hand with digit loss may require multiple procedures over a prolonged period. The authors presented a clinical series of patients in which these types of injuries were reconstructed in a single operation. A chimeric flap based on the anterior tibial vessels was described. A total of three free tissue transfers included an anterior tibial flap, a dorsalis pedis flap, and a great toe wrap-around flap. These triple flaps were transferred to resurface the defects of the mutilated hand, which was involved in the thumb, first web space, volar palm, thenar eminence, or radial aspect of wrist. The cumulative size of the defects ranged from 9 by 11 cm to 12 by 18 cm. The average improvement of thumb opposition was 4.8 on the Kapandji scale. Sensory recovery of the thumb tip of S3 was achieved. There were no major donor-site complications. A chimeric flap based on the anterior tibial vessels is an excellent method of reconstruction of severe multilevel injuries of the hand, including thumb loss.
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Most of the complex wounds in the feet are a direct consequence of peripheral vascular disease resulting from smoking, diabetes, and renal disease. The foot is also commonly injured by trauma. Foot wounds are extremely challenging: they are repeatedly subject to the trauma of walking, dependent edema, and possible insensibility. Furthermore, the skin of the foot is thick and poorly mobile, and local options tend to have limited arcs of rotation. Although amputation is always possible, an intimate understanding of the anatomy of foot flaps can provide an extremely useful range of reconstructive options for successful reconstruction and salvage.

Abductor Digiti Minimi Flap
Flexor Digitorum Brevis Flap
Abductor Hallucis Flap
Dorsalis Pedis Flap
Medial Plantar Artery Flap
Lateral Calcaneal Flap
### ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>Intrinsic muscle of the lateral aspect of the foot on the plantar surface; lies between the flexor digitorum brevis medially and the fifth metatarsal laterally.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>$10 \times 3$ cm.</td>
</tr>
<tr>
<td>Origin</td>
<td>Lateral and medial processes of the calcaneal tuberosity and adjacent intermuscular septum.</td>
</tr>
<tr>
<td>Insertion</td>
<td>Lateral aspect of the base of the proximal phalanx of the fifth toe.</td>
</tr>
<tr>
<td>Function</td>
<td>Minor degree of toe abduction.</td>
</tr>
<tr>
<td>Composition</td>
<td>Muscle, myocutaneous.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type II.</td>
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<tr>
<td>Dominant Pedicle</td>
<td>Proximal branch of the lateral plantar artery.</td>
</tr>
<tr>
<td>Minor Pedicle</td>
<td>Two or three small muscular branches of the distal lateral plantar artery.</td>
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<tr>
<td>Nerve Supply</td>
<td>Lateral plantar nerve, S1-S2.</td>
</tr>
</tbody>
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Section 14A

FOOT

Abductor Digiti Minimi Flap

CLINICAL APPLICATIONS

Regional Use
- Lateral ankle
- Posterior heel
- Dorsal foot

Specialized Use
- Sensate flap to the heel
ANATOMY OF THE ABDUCTOR DIGITI MINIMI FLAP

**Fig. 14A-1**

**Dominant pedicle:** Proximal branch of lateral plantar artery
ANATOMY

Landmarks
Intrinsic muscle of the lateral aspect of the foot on the plantar surface; lies between the flexor digitorum brevis medially and the fifth metatarsal laterally.

Composition
Muscle, myocutaneous.

Size
10 × 3 cm.

Origin
Lateral and medial processes of the calcaneal tuberosity and adjacent intermuscular septum.

Insertion
Lateral aspect of the base of the proximal phalanx of the fifth toe.

Function
Minor degree of toe abduction.

Arterial Anatomy (Type II)

Dominant Pedicle
Proximal branch of the lateral plantar artery

Regional Source
Posterior tibial artery.

Length
2 cm.

Diameter
0.6 mm.

Location
Proximal third of the muscle.

Minor Pedicle
Two or three muscular branches of the lateral plantar artery

Regional Source
Posterior tibial artery.

Length
1 cm.

Diameter
0.5 mm.

Location
Distal two thirds of the muscle.

Venous Anatomy

Accompanying venae comitantes drain into the posterior tibial vein.

Nerve Supply

Motor
Branches of the lateral plantar nerve entering the medial deep surface of the proximal muscle belly.

Sensory
Skin overlying abductor digiti minimi has a dual innervation from the lateral plantar nerve distally and the sural nerve posteriorly, both of these derived from S1-S2.
Vascular Anatomy of the Abductor Digiti Minimi Flap

Fig. 14A-2

Dominant pedicle: Proximal branch of lateral plantar artery (D)

Minor pedicle: Two or three muscular branches of lateral plantar artery
d, Abductor digiti minimi; f, flexor digitorum brevis; h, abductor hallucis; t, lateral plantar artery
Dominant pedicle: Proximal branch of lateral plantar artery (D)
Minor pedicle: Two or three muscular branches of lateral plantar artery (m)
d, Abductor digiti minimi; e, medial plantar artery; f, flexor digitorum brevis; h, abductor hallucis; pt, posterior tibial; t, lateral plantar artery
FLAP HARVEST

Design and Markings
With the patient in the supine position and the ankle dorsiflexed, the muscle is placed under tension on the lateral border of the sole of the foot. Its bulk can be clearly seen, extending from the lateral border of the calcaneal phalanx to the base of the proximal phalanx of the fifth toe. If a skin island is required, a V-Y advancement design is centered along the long axis of the fifth metatarsal, with its base distal to allow distal advancement. If muscle only is required for ankle coverage, an incision can be designed on the plantar-lateral aspect of the foot to expose the lateral border of the muscle. Skin flap dimensions should be no greater than 3 by 8 cm. The site of entry of the dominant pedicle is 4 to 5 cm inferior to the medial medialis.

Patient Positioning
The patient is placed in either the prone or lateral decubitus position.

GUIDE TO FLAP DISSECTION
The abductor digitii minimi muscle is most readily approached through a lateral plantar incision between the fifth metatarsal phalangeal joint and the base of the calcaneus proximally. The skin is incised and dissection is taken down to the lateral plantar fascia, which is incised. The muscle is identified distally at the base of the fifth toe at the level of the metatarsophalangeal phalangeal joint, and the insertion is divided. As the muscle is elevated from distal to proximal, the lateral plantar artery and its associated venae comitantes and nerve are found running between the flexor digitorum brevis and flexor digitii minimi.
Minor pedicles entering the medial border of the muscle are divided while preserving the dominant pedicle. As the muscle crosses the base of the fifth metatarsal, the belly becomes attenuated and can be easily injured. Flap elevation continues proximally to the cuboid bone, where the dominant pedicle can be seen entering the medial deep aspect of the muscle.

Fig. 14A-4
**FLAP VARIANTS**

- Distally based flap
- Reverse flap

**Distally Based Flap**

After the surgeon exposes the muscle as previously described, division is undertaken proximally at the level of the cuboid bone. The lateral plantar artery dominant proximal pedicle is divided, leaving the flap perfused on its distal lateral artery perforators. It can be rotated 180 degrees to fill defects of the distal foot with primary donor site closure.

![Diagram of distally based flap](image-url)

**Fig. 14A-5**

- Area of defect
- Proximal muscle divided at cuboid, and distal tendon cut at base of proximal phalanx
- 180 degrees of rotation possible with perfusion by distal lateral artery perforators
Reverse Flap
The reverse flap incorporates a V-Y advancement concept to allow distal foot closure with a myocutaneous flap. Once the skin island has been incised, the minor and dominant pedicles are identified, and the muscle origin is cut proximally to allow distal advancement. Both the major and minor blood supplies are preserved with this flap.

**ARC OF ROTATION**
The proximally based flap rotates 90 to 100 degrees to cover the lateral malleolus and almost 160 degrees to cover the lateral plantar heel.
FLAP TRANSFER
The flap is either advanced in a V-Y fashion or is transposed either directly or through a subcutaneous tunnel into its recipient bed.

FLAP INSET
In a muscle flap, the distal tendinous insertion can be used as a strong anchor point to hold the flap in its new location. In a V-Y myocutaneous configuration, sutures should be placed full thickness through the dermis to prevent epidermal tearing when sutures are placed too superficially.

DONOR SITE CLOSURE
Direct closure is feasible in a muscle flap. In the V-Y configuration, the flap is advanced and the donor site V is closed to a Y proximally. Adequate release of adipofascial attachments is required proximally to facilitate distal advancement.

CLINICAL APPLICATIONS
This patient had extensive full-thickness tissue loss following open reduction internal fixation of a comminuted calcaneal fracture resulting from trauma; there was exposed bone and hardware. The abductor digiti minimi flap was dissected from distal to proximal based on its antegrade dominant blood supply and turned over to cover the defect. A small split-thickness skin graft was necessary for complete closure.

Fig. 14A-8  A, The lateral calcaneal defect is seen, with exposed bone and hardware with soft tissue loss. B, The abductor digiti minimi flap was turned over to cover the defect. C, A split-thickness skin graft was harvested and affixed over the top of the muscle flap. D, The final result is seen. (Case courtesy Christopher E. Attinger, MD.)
This patient presented with a chronic posterolateral heel wound with exposed necrotic bone and evidence of osteomyelitis on preoperative imaging and biopsy. After thorough debridement to clean noninfected bone and soft tissue, the abductor digiti minimi flap was harvested based on its antegrade dominant vascular pedicle and turned 180 degrees. The muscle flap was then covered with a split-thickness skin graft, and a strict offloading protocol was instituted in the postoperative period. Complete healing of the wound with durable coverage was achieved.

Fig. 14A-9  A, The patient had a chronic nonhealing wound of the posterolateral heel with underlying osteomyelitis. B, The abductor digiti minimi muscle was detached from its distal insertion and dissected to the level of its dominant vascular pedicle. C, The muscle was turned 180 degrees and inset into the wound. D, The final result following muscle coverage and skin grafting. (Case courtesy Christopher E. Attinger, MD.)
After a cuboidectomy for osteomyelitis, this patient presented with a 4 by 5 by 2 cm defect of the plantar foot with exposed bone at the base. An external fixator had been placed during the initial debridement for Charcot reconstruction. Coverage of the exposed bone at the base of the wound and obliteration of dead space were necessary. An incision was made along the glabrous junction, and the abductor digiti minimi was divided at the fifth metatarsal joint. A subcutaneous tunnel underneath the lateral plantar skin was made for the muscle to rotate in and fill the defect. A large V-Y fasciocutaneous flap was designed and incised to the level of the plantar fascia and mobilized. The defect was successfully closed using a combination of the abductor digiti minimi flap and a V-Y fasciocutaneous flap.

Fig. 14A-10  A, Plantar foot wound with exposed bone at the base following a cuboidectomy. B, Abductor digiti minimi muscle elevated and tunneled underneath the lateral plantar skin to aid in obliteration of dead space. C, Design of the medial plantar V-Y fasciocutaneous flap. D, Mobilization of the V-Y fasciocutaneous flap. E, The result is seen 1 month postoperatively. (Case courtesy Christopher E. Attinger, MD.)
This patient had a chronic anterolateral ankle wound with exposed necrotic bone and evidence of osteomyelitis on preoperative imaging and biopsy. Following thorough debridement to clean noninfected bone and soft tissue, the abductor digiti minimi flap was harvested based on its antegrade dominant vascular pedicle and inset into the wound. The muscle flap was then covered with a split-thickness skin graft, and a strict offloading protocol was instituted in the postoperative period. Complete healing of the wound with durable coverage was achieved.

**Pearls and Pitfalls**

- Surgery is most easily conducted under tourniquet control to avoid injuring the pedicle.
- Patency of the posterior tibial circulation is essential for this flap to survive. If the posterior tibial pulse is not palpable at the level of the medial malleolus, an arteriogram must be performed to confirm patency of the source vessel.
- Incisions for exposure of the muscle flap should not be placed on weight-bearing skin.
- The muscle is only suitable for small defects because of its narrow diameter.
- The V-Y fasciocutaneous flap based proximally has lower donor site morbidity than the reverse myocutaneous flap.
- The distally based flap can only survive if the deep plantar arch is patent. If the dorsalis pedis artery pulse is absent dorsally, this represents a relative contraindication to the use of the distally based flap.

**Fig. 14A-11**  
A, Chronic nonhealing wound of the anterolateral ankle with underlying osteomyelitis.  
B, The abductor digiti minimi muscle detached from its distal insertion and dissected to the level of its dominant vascular pedicle.  
C, The muscle was turned and inset into the wound.  
D, The result after muscle coverage and skin grafting. (Case courtesy Christopher E. Attinger, MD.)
EXPERT COMMENTARY
Matthew Endara, Christopher E. Attinger

Indications
In our practice the abductor digit minimi muscle flap has been very useful for providing coverage of small lateral heel, lateral calcaneus, lateral midfoot, and ankle wounds when based on the dominant pedicle off of the lateral plantar artery. This muscle flap has also been described for use on the lateral distal foot and toes when it is raised on its distal blood supply.

Advantages and Limitations
Chief among the advantages of the type II abductor digit minimi muscle flap is its reliability and consistent vascular anatomy, which makes dissection quick and relatively easy. When healed, this muscle flap provides durable coverage, even over weight-bearing surfaces of the foot. In addition, harvesting this flap leaves minimal donor site morbidity. Finally, the location of the muscle in the foot allows surgery to be performed under regional anesthesia, thereby avoiding the potential complications of general anesthesia in high-risk patients.

The limitations of the abductor digit minimi are related mostly to both the muscle size and the length of its vascular pedicles. The small size of the abductor digit minimi muscle limits its use for larger defects and occasionally requires raising it in combination with surrounding local tissue flaps to achieve needed coverage. Because the wounds needing such a flap are frequently found in patients with diabetes mellitus and peripheral vascular disease, existing atherosclerosis can impact the harvest of this muscle as a flap. Patency of the lateral plantar artery branch with either antegrade or retrograde flow is necessary; this must be confirmed before a flap is attempted, through clinical examination, duplex ultrasound, or angiography. If any occlusion exists in the region of the dominant pedicle takeoff, this flap should not be attempted.

Anatomic Considerations
The abductor digit minimi is a triangular muscle with a wide posterior origin extending from the medial to lateral process of the calcaneus along with the adjacent intermuscular septum. The bulk of the muscle is found proximal to the proximal portion of the fifth metatarsal. As it proceeds distally, the muscle slowly narrows to form a tendon at the base of the fifth metatarsal. It ultimately inserts on the lateral side of the proximal phalanx of the little toe with the flexor digiti minimi brevis.

Anatomic variation can exist, with separate muscle bellies that stop and start at the base of the fifth metatarsal. The dominant pedicle to the muscle arises from the lateral plantar artery and enters the muscle on its medial surface close to its origin. As the lateral plantar artery courses laterally between the flexor digitorum brevis muscle and the quadratus planus muscle, it gives off two or three additional minor pedicles on the dorsal medial surface of the muscle. Because the lateral plantar artery communicates with the medial plantar artery and the dorsalis pedis artery at the plantar interspace between the proximal first and second metatarsal bone, the flow along the lateral plantar can be antegrade or retrograde.

Personal Experience and Insights
In 2002 we performed a retrospective review of our experience using intrinsic muscles of the foot as local muscle flaps for coverage of wounds in which bone, tendon, nerve, or vascular structures were exposed. Within that series, there were 19 cases in which the abductor digit
minimi flap was used for lateral heel and ankle ulcers. Patients were diabetic and nondiabetic alike. Overall, the flap had a success rate of 96%, which was comparable to microsurgical reconstruction in a similar patient population.1,2

The flap was most frequently used for coverage of calcaneal defects following debridement for osteomyelitis. The defect was either filled with antibiotic-impregnated methylmethacrylate beads or with tendon itself. The muscle was also successfully used to cover lateral and posterolateral heel defects. Skin grafting was necessary in all cases. The methylmethacrylate was replaced with bone graft 6 weeks after the course of antibiotics was completed without recurrent infection.

A critical step in using this flap is to ensure that all infected tissue is debrided and that postdebridement cultures are negative before attempting to close the wound. More mobilization could be achieved by detaching the muscle off its origin from the calcaneus. If the defect is large, it can be harvested with the flexor digitorum brevis muscle. We have also used it in combination with the abductor hallucis brevis muscle.

We have not attempted to harvest this flap as a myocutaneous unit with a V-Y design or based on its distal minor pedicles, so we cannot comment on its utility or success rates.

Recommendations
Planning
Optimization of the wound environment, including complete and thorough debridements until negative cultures are achieved, is necessary before attempting definitive closure. Co-morbidities must be optimized as well, especially in a patient with diabetes mellitus, chronic steroid use, end-stage renal disease, nutritional deficiencies, and peripheral artery disease. If peripheral artery disease is present, the patient should undergo a vascular workup before flap reconstruction is attempted, including a detailed Doppler examination, duplex ultrasound, and/or a preoperative angiogram with magnified foot views. Finally, postoperative expectations must be discussed with the patient, including the necessity of postoperative offloading and skin grafting as part of the procedure.

Technique
The procedure begins with identification and marking of the fifth metatarsal-phalangeal joint and lateral heel at the glabrous junction between the dorsum and sole of the foot. These two points are connected with a line along the glabrous junction for the planned incision. Following incision and dissection down to the level of the muscle, the tendon is visualized as it inserts on the fifth metatarsal joint. The tendon is divided and teased off the flexor digitorum brevis muscle. This separation of the two muscles can be easier if the dissection starts proximal to the fifth metatarsal and extends distally. To minimize trauma on the muscle and potential damage to the vascular pedicle during dissection, a single suture is placed in the freed distal tendon to serve as a temporary leash to manipulate the muscle. The minor pedicles are usually found proximal to the proximal fifth metatarsal. Dissection can then proceed from distal to proximal, with either suture ligation or bipolar electrocautery of any intervening minor perforators along the way. The dominant pedicle is deep into the fossa at the proximal pole of the cuboid entering the muscle from medial to lateral. To make certain that a proximal minor dominant pedicle is not the dominant pedicle, one can gently compress the minor pedicle with a vascular pickup and listen for blood flow within the muscle with a Doppler device. Once the dominant pedicle has been identified, the origin of the muscle can then be safely detached to allow extra muscle mobilization.

Continued
The muscle flap is now ready to be rotated to fill defects of the lateral heel, calcaneus, lateral foot, or midfoot. Following insertion of the muscle, a split-thickness skin graft is harvested and secured atop the muscle flap with a vacuum-assisted closure device.

The donor site for the muscle flap can be closed primarily. Care should be taken not to compress the muscle flap during the closure. Tight sutures should be removed and the resultant tissue gap skin grafted. If the muscle flap is combined with another local fasciocutaneous flap, the muscle is secured in place and covered with the local flap.

**Postoperative Care**

At the completion of surgery, the ankle joint is immobilized in the neutral position to minimize motion of the flap inset as well as the skin graft, if present. The negative pressure wound therapy used to assist with skin graft take can be removed on postoperative day 3 to 5. Once the incision lines are healed, typically after 2 to 4 weeks, range of motion exercises can begin on the ankle joint. Offloaded protection of the flap continues to be important, however, using either a postoperative splint, a Cam walker (not to be used for ambulation), or cast until the incision lines, flap inset, and skin graft are completely healed.

**Complications**

Although there is minimal donor site morbidity associated with loss of the abductor digiti minimi muscle, postoperative complications include hematoma, infection, and dehiscence of donor site suture lines. Failure of the flap itself can be avoided by making certain that the wound is infection free before reconstruction and by meticulous attention to detail when dissecting around the vascular pedicle. Dehiscence of the wound and donor site should be avoided with a strict offloading regimen until the wounds have healed. Infection compromising the flap can be seen when definitive coverage of previously infected wounds is attempted on wounds that were inadequately debrided or for which inappropriate postoperative antibiotic therapy has been given.

**Take-Away Messages**

- Thorough debridement of wounds is critical before flap reconstruction is attempted and bacteria-specific antibiotic therapy is initiated.
- Given its small size, the applications of the abductor digiti minimi are limited to smaller wounds within its range of mobilization.
- A split-thickness skin graft is usually preferable to raising the flap as a myocutaneous unit because the donor deficit would be over a weight-bearing portion of the foot that would pose severe problems in the future.
- Flap protection in the postoperative period with ankle immobilization and pressure offloading is critical to limit shearing of the flap inset and the donor site incision line.

**References**

Bibliography With Key Annotations


Local muscle flaps, pioneered by Ger in the late 1960s, were extensively used for foot and ankle reconstruction until the late 1970s, when, with the evolution of microsurgery, microsurgical free flaps became the reconstructive method of choice. To assess whether the current underuse of local muscle flaps in foot and ankle surgery is justified, the authors identified from the Georgetown Limb Salvage Registry all patients who underwent foot and ankle reconstruction with local muscle flaps and microsurgical free flaps from 1990 through 1998. By protocol, flap coverage was the reconstructive choice for defects with exposed tendons, joints, or bone. Local muscle flaps were selected over free flaps if the defect was small (3 by 6 cm or less) and within reach of the local muscle flap. During the same time frame, the authors performed 50 microsurgical free flaps (96% success rate) in the same areas when the defects were too large or out of reach of local muscle flaps. Thirty-two consecutive patients underwent local muscle flap reconstruction for 19 diabetic wounds and 13 traumatic wounds. Diabetes did not significantly affect healing and limb salvage rates. However, diabetes did affect healing times (a twofold increase), length of stay (2.7 times as long), and long-term survival (63% survival in diabetic patients versus 100% in the trauma group). Local muscle flaps provide a simpler, less expensive, and successful alternative to microsurgical free flaps for foot and ankle defects that have exposed bone (with or without osteomyelitis), tendon, or joint at their base. Diabetes does not appear to adversely affect the effectiveness of these flaps. Local muscle flaps should remain on the forefront of possible reconstructive options when treating small foot and ankle wounds that have exposed bone, tendon, or joint.


Pedicled muscle flaps should always be considered as a reconstructive option when evaluating a defect around the foot and ankle. To gain confidence in using this option, the surgeon must perform multiple anatomic dissections with special attention to the vascular anatomy. These dissections also should give the surgeon a feel for the reach of the various flaps and their applicability in various circumstances. For optimal results, the intraoperative dissections should be performed with loupes and Doppler ultrasound to allow the surgeon to identify and protect the dominant pedicle. When insetting the flap, special care must be taken to avoid placing excessive tension or tension on the pedicle so that the blood flow is not compromised. Both arterial and venous flow should be assessed after insetting the muscle with the Doppler. Pedicled muscle flaps offer a rapid and easy solution to difficult soft tissue problems around the foot and ankle. The operation can be performed with a regional block in under 2 hours. The postoperative stay is short, and the donor defect is minimal. Pedicled muscle flaps offer a great alternative to microsurgical free flaps, especially in the sick patient. They should be considered more often when looking at how to fill small defects with exposed bone or osteomyelitis around the foot and ankle.


Ian Taylor introduced the angiosome concept, separating the body into distinct three-dimensional blocks of tissue fed by source arteries. Understanding the angiosomes of the foot and ankle and the interaction among their source arteries is clinically useful in surgery of the foot and ankle, especially in the presence of peripheral vascular disease. In 50 cadaver dissections of the lower extremity, the authors injected arteries with methylmethacrylate in different colors and dissected them. Clinically, each reconstructive patient’s vascular anatomy was routinely analyzed preoperatively using a Doppler instrument, and
the results were evaluated. The authors concluded that detailed knowledge of the vascular anatomy of the foot and ankle allows the plastic surgeon to plan vascularly sound reconstructions, the foot and ankle surgeon to design safe exposures of the underlying skeleton, and the vascular surgeon to choose the most effective revascularization for a given wound.


Noting that the effectiveness of pedicled muscle flaps versus microsurgical free flaps in patients with diabetes mellitus for complex foot and ankle reconstruction has not been well defined, from the Georgetown Wound Registry the authors identified all patients who underwent pedicled muscle flap or free flap reconstruction from 1990 to 2000 with 8.1 ± 3.1-year follow-up. Thirty-eight diabetic and 42 nondiabetic patients were identified. Flap coverage was the reconstructive choice for defects with exposed tendons, joints, or bone, with pedicled muscle flaps always selected for smaller defects. Thirty-two patients received 34 pedicled muscle flaps for 34 wounds, whereas 48 received 52 free flaps for 51 wounds. Thirty-one of 34 wounds covered with pedicled muscle flaps went on to heal, for a 91% success rate, a 94% limb salvage rate, and a 78% patient survival rate. There were 15 complications among 45 reconstructive procedures, for an overall 33% complication rate. Forty-eight of the 51 wounds covered with free flaps went on to heal, for a 94% healing rate, a 96% limb salvage rate, and a 77% patient survival rate. There were 17 complications among 93 reconstructive procedures, for an 18% complication rate. Diabetes does not appear to affect the success of pedicled muscle flap or free flap reconstruction except for requiring more debridements, longer healing times, and decreased long-term survival. When compared with historical diabetic controls with amputation, however, limb salvage appears to prolong survival of diabetic patients. Pedicled muscle flaps appear to be as effective as free flaps for the coverage of small complex foot and ankle defects, despite the postoperative complication rate. Diabetes is not a contraindication to either type of flap reconstruction for limb salvage.


Congenital hypertrophic muscles of the foot are rare; a search of the literature revealed only a few select cases on the subject. However, a patient was treated at Saint Michael’s Medical Center for a congenitally hypertrophic abductor digiti minimi muscle of the right foot. Surgical exploration also revealed slight abnormalities of the third and fourth plantar interosseous muscles. However, these muscles were left intact because they were not symptomatic. There were no other hypertrophic muscles noticed on this foot, and none in the opposite foot. Excision of the entire hypertrophic muscle eventually provided complete relief and allowed the patient to wear normal foot gear. This article described a case presentation of a single congenitally hypertrophic muscle with reference to its clinical evaluation and subsequent treatment.


The coverage of ulcers or scar tissue on the dorsum of the foot is often difficult to accomplish with skin grafts. The author presented the use of the abductor digiti minimi and abductor hallucis as transposition flaps as a technique to provide such coverage. However, these muscles are small, with a limited arc of rotation, and will only cover defects located close to the medial or lateral aspect of the dorsum of the foot.


In this anatomic study of amputated limb specimens from patients who have peripheral vascular disease, the authors injected the vasculature with latex and studied the blood supply to each of the lower leg flaps that have clinical applications for coverage of exposed bone in the lower extremity. Their studies included the gastrocnemius, soleus, flexor digitorum longus, peroneus longus, peroneus brevis, abductor
hallucis, abductor digiti minimi, and flexor digitorum brevis. They described this muscle for coverage of defects around the lateral malleolus. In their dissections, the arterial supply was consistently derived from a branch of the lateral plantar artery entering the muscle close to its origin.


A rare case of an isolated congenital muscle hypertrophy involving the abductor hallucis muscle was presented. The authors noted that although the entity had not been well described previously, it should be entertained in the different diagnoses of medial childhood foot masses. The diagnoses of such masses should be made more easily with the widespread availability of magnetic resonance imaging. Treatment is generally straightforward, consisting of observation alone, versus partial or total excision, as dictated by the operative findings and previous functional impairment.


The authors described the most common options available for reconstruction of the foot. The foot is considered a group of different regions, and it is helpful to classify it into four different anatomic and functional areas. The planning and final outcome of the reconstruction are based on the type of flap available for a specific defect in one of these four territories.


The use of free flaps to repair defects of the leg or foot is a viable alternative to cross-leg flaps because (1) the total time of immobilization and hospitalization is less, (2) the total number of general anesthetics is less, and (3) the morbidity and costs are less. Increased experience will enhance the survival statistics for free flaps, making their use the method of choice for the reconstruction of defects in the distal part of the lower extremity.


The abductor digiti minimi muscle flap is known as good tissue coverage for the lateral ankle and heel. For reconstruction of the distal portion of the foot, the distally based flap of this muscle can be useful, effectively using the blood supply through the plantar arch communication. The authors reported a case of frostbite of the right fifth toe that they successfully repaired with a distally based abductor digiti minimi muscle flap. They also presented information on distally based use of the muscles of the foot.
ANATOMIC LANDMARKS

**Landmarks**
Muscle lies deep to the plantar fascia in the sole of the foot, extending between the medial border of the calcaneus to the middle phalanges of the toes. It is bordered medially by the abductor hallucis and laterally by the abductor digiti minimi.

**Size**
10 × 4 cm.

**Origin**
Medial process of the calcaneus, plantar aponeurosis, and intermuscular septum.

**Insertion**
Into the middle phalanges of the second to fifth toes.

**Function**
Initiation of flexion of the toes. Its function is expendable if a fully functional flexor digitorum longus is present.

**Composition**
Muscle.

**Flap Type**
Type II.

**Dominant Pedicles**
Proximal branch of the medial plantar artery and proximal branch of the lateral plantar artery.

**Minor Pedicles**
Two or three distal muscular branches of the same vessels.

**Nerve Supply**
Medial plantar nerve.
Section 14B

FOOT

Flexor Digitorum Brevis Flap

CLINICAL APPLICATIONS

Regional Use
Defects of foot and heel
ANATOMY OF THE FLEXOR DIGITORUM BREVIS FLAP

**Fig. 14B-1**

**Dominant pedicles:** Proximal branch of medial plantar artery; proximal branch of lateral plantar artery
ANATOMY

Landmarks  Muscle lies deep to the plantar fascia in the sole, extending between the medial border of the calcaneus and the middle phalanges of the toes. It is bordered medi-ally by the abductor hallucis and laterally by the abductor digiti minimi. When a skin island is incorporated, it should be placed over the medial and central non-weight-bearing skin of the sole measuring a maximum of $12 \times 5$ cm.

Composition  Muscle.

Size  Muscle $10 \times 4$ cm; skin $12 \times 5$ cm.

Origin  Medial process of the calcaneus, plantar aponeurosis, and intermuscular septum.

Insertion  Into the middle phalanges of the second to fifth toes

Function  Initiation of flexion of the toes. Its function is expendable if a fully functional flexor digitorum longus is present.

Arterial Anatomy (Type II)

Dominant Pedicle  *Proximal branch of the medial plantar artery*

**REGIONAL SOURCE**  Posterior tibial artery.

**LENGTH**  1 to 2 cm.

**DIAMETER**  0.6 mm.

**LOCATION**  Medial deep surface of the muscle proximally.

Dominant Pedicle  *Proximal branch of the lateral plantar artery*

**REGIONAL SOURCE**  Posterior tibial artery.

**LENGTH**  1 to 2 cm.

**DIAMETER**  0.6 mm.

**LOCATION**  Pedicle enters the lateral deep surface of the muscle proximally.

Minor Pedicle  *Two or three muscular branches of medial plantar artery*

**REGIONAL SOURCE**  Posterior tibial artery.

**LENGTH**  1 cm.

**DIAMETER**  0.5 mm.

**LOCATION**  Medial aspect of the muscle belly.

Minor Pedicle  *Two muscular branches of the lateral plantar artery*

**REGIONAL SOURCE**  Posterior tibial artery.

**LENGTH**  1 cm.

**DIAMETER**  0.5 mm.

**LOCATION**  Lateral aspect of the muscle belly.

Venous Anatomy

Venae comitantes accompany the arteries to the source draining the posterior tibial veins.

Nerve Supply

Motor  Branch of the medial plantar nerve that enters the muscle proximally on its deep surface adjacent to the muscles.

Sensory  Medial calcaneal nerves S1 and S2 and medial plantar nerves L4 and L5 innervate the skin overlying the medial and proximal portions of the muscle. The lateral plantar nerves S1 and S2 provide further innervation over the lateral distal sole.
VASCULAR ANATOMY OF THE FLEXOR DIGITORUM BREVIS FLAP

**Fig. 14B-2**

*d*, Abductor digiti minimi; *e*, medial plantar artery; *f*, flexor digitorum brevis; *h*, abductor hallucis; *t*, lateral plantar artery
Dominant pedicles: Proximal branch of medial plantar artery ($D_1$); proximal branch of lateral plantar artery ($D_2$)

Minor pedicles: Two or three muscular branches of medial plantar artery ($m_1$) and two muscular branches of lateral plantar artery ($m_2$)

d, Abductor digiti minimi; e, medial plantar artery; f, flexor digitorum brevis; h, abductor hallucis; pt, posterior tibial artery; t, lateral plantar artery
FLAP HARVEST
Design and Markings
When a simple muscle flap is to be used, a linear incision along the length of the third metatarsal provides excellent exposure of the muscle. If a skin island is planned, it is centered more medially over the non-weight-bearing skin of the instep, based over the fourth to third metatarsals. If fascial extensions are required, the fascial dissection can be carried out toward the medial aspect of the fifth metatarsal, but no farther.

Muscle position centered over third metatarsal
Marking for incision for muscle flap elevation
To avoid weight-bearing areas of foot

Fig. 14B-3
Patient Positioning
The patient is placed in the prone, supine, or lateral decubitus position.

GUIDE TO FLAP DISSECTION
Standard Flap
The midplantar vertical incision is opened and the plantar fascia is divided.

Dissection is carried out distally over the tendons at the level of the second through fourth metatarsal phalangeal joints. The tendons are divided at that level, and the muscle is dissected proximally toward its origin from the calcaneus.

Fig. 14B-4

A

Longitudinal plantar incision with linear incision of plantar fascia beneath

B

Flexor digitorum brevis muscle exposed deep in sole

C

Distal tendon division
This maneuver will expose the underlying tendons of the flexor digitorum longus. The minor distal pedicles encountered during this elevation arise from the medial plantar artery and are divided. Toward the base of the origin, the dominant pedicles will be identified and should be preserved. The muscle is now ready for turnover to cover the calcaneus.

Myocutaneous Flap

If a myocutaneous flap is planned, it can be based proximally with a dissection similar to the standard flap just described. The skin island is based over the second and third metacarpals centrally. The lateral edge is located medial to the fourth metatarsal and extends medially to the intermuscular septum between flexor digitorum brevis and the abductor hallucis muscles. The longitudinal skin edges are incised and dissection is taken down through the plantar fascia until the superficial aspect of the flexor digitorum brevis is identified. The plantar fascia medial and lateral to the skin island is retracted to allow elevation of the flap. The four flexor tendons are divided at the level of the metatarsal phalangeal joint, and the
muscle is then dissected from distal to proximal. The lateral plantar artery and associated venae comitantes are divided in the midfoot and are included with the flap. The lateral plantar nerve is not included with the flap. If a neurosensory flap is planned, however, the sensory branches of the medial plantar nerve entering the skin island are dissected from the main nerve trunk. The distal minor pedicles of the medial plantar artery can then be divided. Once the course of the lateral plantar artery beneath the proximal muscle belly is clearly identified, the flap can be divided at its origin to allow complete mobilization. If further mobility is required, the origin of the abductor hallucis has to be divided, allowing the lateral plantar artery to be traced proximally to its junction with the posterior tibial artery.

**FLAP VARIANT**

**Reverse Flap**

The reverse flap requires the integrity of the distal plantar arch, with adequate dorsalis pedis arterial inflow. The muscle elevation is similar to that of the standard flap, differing only in that the muscle is advanced distally for distal foot defects.

Reverse flap

*Fig. 14B-5*
ARC OF ROTATION

Standard Flap and Myocutaneous Flap
The flap is used as a turnover flap to cover the calcaneus based on the lateral plantar artery circulation. With extensive mobilization, the flap can reach the ankle.

Reverse Flap (Muscle or Myocutaneous V-Y Advancement)
The distally based flap can be transposed to cover lateral and distal foot defects. If a V-Y advancement is used, the distal advancement is about 2 to 3 cm maximally.
FLAP TRANSFER
Standard flap transfer involves 180-degree rotation over the calcaneus. A shave osteotomy of the plantar aspect of the calcaneus will allow more of the thicker waist of the muscle to provide a weight-bearing pad over the bone.

FLAP INSET
The muscle is sutured to the surrounding soft tissue with absorbable sutures, and exposed muscle is skin grafted. The skin islands should be sutured with well-placed skin sutures, incorporating adequate bites of the dermis.

DONOR SITE CLOSURE
When possible, the plantar fascia should be repaired in the midline when a simple linear midsole incision is performed. Simple skin closure is routinely done.
CLINICAL APPLICATIONS
This 61-year-old woman had stepped on a nail and sustained a penetrating injury to her plantar heel pad. She required hospitalization for severe cellulitis, which was managed with bed rest, elevation, and intravenous antibiotics. Following a prolonged recovery, she began to have pain when bearing weight on the heel. Examination revealed almost complete loss of the subcutaneous fat of her plantar heel pad and an associated small bursa. Padding was restored with the use of a turnover flap of the flexor digitorum brevis muscle and plantar fascia, buried beneath the plantar heel skin.

Fig. 14B-8  A, The patient had loss of subcutaneous fat of her heel pad subsequent to a puncture injury, with resultant infection. B, Lateral view of the heel pad contour. C, The bursal space overlying the calcaneus was opened and debrided through a small transverse incision. The flexor digitorum brevis muscle and its overlying plantar fascia was exposed through a midline plantar incision that stopped short of the transverse heel pad incision. D, The flexor brevis muscle, with the attached plantar fascia, was turned over from distal to proximal after the division of the flexor digitorum brevis tendons. It could then be inset into the debrided bursal space overlying the bone. E, Postoperatively, the improved heel pad permits painless ambulation, and plantar scars are barely visible. (Case courtesy Lawrence Colen, MD.)
This 68-year-old diabetic woman had previously undergone closure of a neurotrophic ulcer over the plantar heel with a heel pad rotation flap. A residual bony prominence contributed to a small recurrence. Resection of the prominence and soft tissue debridement were performed. A turnover flap of the flexor digitorum brevis muscle with attached plantar fascia provided adequate bulk on which a skin graft could be placed.

Fig. 14B-9  A, The patient’s recurrent plantar heel ulceration after prior closure with a heel pad rotation flap and skin graft to the donor site. B, A plantar midline incision exposed the plantar fascia with the flexor digitorum brevis muscle just deep to the fascia. C, The muscle flap and overlying fascia were turned over into the debrided wound and covered with a thick split-thickness skin graft. (Case courtesy Lawrence Colen, MD.)
Pearls and Pitfalls

- Dissection is done under tourniquet control to avoid neurovascular injury.
- The patency of the posterior tibial circulation should always be confirmed preoperatively—if necessary, with angiographic visualization.
- In harvesting the muscle distally, the surgeon must preserve the long flexors of the toes to maintain foot function.
- The flap is best based on the lateral rather than the medial plantar circulation.
- Great care should be exercised when performing this procedure on patients with arterial disease, because the standard flap will result in division of the distal-lateral plantar artery; an occluded dorsalis pedis inflow can then precipitate ischemia of the distal foot.
- Great care should be exercised when performing this procedure on patients with arterial disease, because the standard flap will result in division of the distal-lateral plantar artery; an occluded dorsalis pedis inflow can then precipitate ischemia of the distal foot.
- In spinal cord–injured patients with heel ulcers, the muscles of the foot will have atrophied substantially, resulting in a much smaller volume of muscle being available for heel coverage than would ordinarily be the case.
- This flap is generally not suitable for posterior heel coverage.

EXPERT COMMENTARY
Lawrence Colen

Indications
Historically, the description of the use of the intrinsic foot muscles for the closure of small foot wounds preceded the advent of negative-pressure wound care systems. Many of the wounds that would have been closed with such muscle flaps are now managed with “the VAC.” Despite this, the intrinsic muscles of the foot remain a very useful local flap option when the surgeon is faced with specific wounds about the heel and ankle.

These flaps are based on antegrade blood flow in the posterior tibial artery and its medial plantar and lateral plantar branches; hence it is important, especially in diabetic patients, to make certain that these branches are patent and fulfill this requirement. Listening over these branches with a handheld Doppler probe while occluding the dorsalis pedis artery will provide the necessary information. These flaps are relatively easy to elevate and transpose, and healing is usually uncomplicated in a properly selected patient. The prime disadvantage of these flaps is their relatively small size, which limits the type of defect they can be used to close. Thus they are selected with much less frequency than the more versatile medial plantar artery flap (instep island flap).

Anatomic Considerations
The flexor digitorum brevis muscle is the largest of the intrinsic muscles described for local transposition. Increased flap bulk is usually obtained by including the plantar fascia with the underlying muscle when elevating and transposing this flap. I have never taken the flap with an overlying skin island, because it is far more useful to use the medial plantar artery flap (instep island flap) when plantar skin is needed. Depending on the extent of the pedicle dissection, the flap can theoretically reach the ankle and posterior hindfoot/Achilles region. I have not used this flap in these locations, because there are other local and/or regional options that are better suited.
Personal Experience and Insights
I find that the flexor digitorum brevis muscle flap is most useful for management of the heel pad. I have used this muscle flap, with an overlying skin graft, for surface soft tissue replacement on the plantar heel, but I have not been happy with the durability of the skin grafts when used on this weight-bearing surface. I have primarily used this flap to replace the loss of subcutaneous tissue overlying the calcaneus in patients with indolent heel pad infections. These patients ambulate with pain, because their heel skin directly opposes the underlying calcaneus.

Recommendations

Technique
The patient should be placed in the prone position on the operating table, and a thigh tourniquet should be used. If the patient has had either a bypass graft to the calf or an endovascular procedure within the previous 6 months, I simply exsanguinate the limb with an Esmarch bandage, using the Esmarch as a tourniquet in the distal leg rather than employing a thigh tourniquet.

The skin incision is made through a midplantar approach, elevating the plantar skin and subcutaneous fat off the plantar fascia for several centimeters medially and laterally. Because the great and small toes have their own short flexor muscles, skin elevation only has to encompass the middle third of the width of the foot. I carefully divide the plantar fascia in the forefoot and look for the tendons of the flexor digitorum brevis so that each tendon can be divided. The digital nerves and vessels to the toes course just below the plantar fascia and can be easily damaged. The muscle flap and the attached plantar fascia may then be elevated in a retrograde fashion, stopping just short of the muscle’s origin from the distal aspect of the calcaneus.

The most important branches from the medial and lateral plantar vessels enter the muscle very close to its origin from the calcaneus, so the more distal branches to the muscle may be divided without concern. When the flap is used for heel pad repair, there is no need to divide the muscle’s origin, because the flap may simply be turned over, like a page of a book, to fill the defect.

The flap inset can be assisted by placing sutures from the tendinous portion of the muscle to the distalmost aspect of the defect. When I use the flap for heel pad soft tissue reconstruction, I often place a “pull-out” polypropylene suture, tying it over a small pledget. The donor site is closed over a small suction drain that is left in place for 2 to 5 days.

Postoperative Care
After surgery, the limb is immobilized in a well-padded short leg splint and the patient is confined to bed rest with limb elevation, or wheelchair use with the affected limb elevated. In most cases the patient may be permitted to ambulate with crutches if good Ace wrap support of the operative site is provided.

Postoperative swelling should be avoided at all times. Skin sutures are removed at 3 weeks. Any callus that has developed around the sutures is debrided at that time. Weight-bearing ambulation is not begun for 3 to 4 weeks after surgery, although this time frame may be a bit longer if there are small wounds associated with the suture sites.

Take-Away Messages
The utility of the flexor digitorum brevis muscle flap has decreased over the years, with many of its early indications now being replaced with either use of negative-pressure wound therapy or the medial plantar artery flap. I continue to use it for subcutaneous heel pad reconstruction.

Local muscle flaps, pioneered by Ger in the late 1960s, were extensively used for foot and ankle reconstruction until the late 1970s, when, with the evolution of microsurgery, microsurgical free flaps became the reconstructive method of choice. To assess whether the current underuse of local muscle flaps in foot and ankle surgery is justified, from the Georgetown Limb Salvage Registry the authors identified all patients who underwent foot and ankle reconstruction with local muscle flaps and microsurgical free flaps from 1990 through 1998. By protocol, flap coverage was the reconstructive choice for defects with exposed tendons, joints, or bone. Local muscle flaps were selected over free flaps if the defect was small (3 by 6 cm or less) and within reach of the local muscle flap. During the same time frame, the authors performed 45 free flaps (with a 96% success rate) in the same areas when the defects were too large or out of reach of local muscle flaps. Thirty-two consecutive patients underwent local muscle flap reconstruction for 19 diabetic wounds and 13 traumatic wounds. Diabetes did not significantly affect healing and limb salvage rates; however, diabetes did affect healing times (twofold increase), length of stay (2.7 times as long), and long-term survival (63% survival in diabetic patients versus 100% in the trauma group). The authors concluded that local muscle flaps provide a simpler, less expensive, and successful alternative to microsurgical free flaps for foot and ankle defects that have exposed bone (with or without osteomyelitis), tendon, or joint at their base. Diabetes does not appear to adversely affect the effectiveness of these flaps. Local muscle flaps should remain on the forefront of possible reconstructive options when treating small foot and ankle wounds that have exposed bone, tendon, or joint.


It is difficult to resurface skin defects of the sole because of its unique anatomy, which is resistant to mechanical stimuli. Although various methods have been reported, few are functionally satisfactory, and it is especially difficult to repair the distal plantar area. The authors reported a reconstruction of the distal plantar area using a flexor digitorum brevis muscle flap based on a reverse flow lateral plantar artery pedicle in a patient with a malignant melanoma on the right lateral metatarsal head of the fifth toe. The muscle flap was sufficient to cover the exposed fifth metatarsal and was covered with a full-thickness skin graft. The result was favorable, and the patient had a normal gait and no pressure sores.


The authors presented their investigation of variations of the musculus flexor digitorum brevis. They examined 33 feet from 15 embalmed adult cadavers and three patients’ lower extremities. Of the 33 feet examined, 18 differed from the classical description given in anatomic textbooks. The muscle belly for the fifth toe was much smaller than the others in 12 feet and was missing in 6 feet. Two cases had extreme variations. In the left foot of one female cadaver, the flexor digitorum brevis was formed by a superficial and deep head, which had three muscle bellies and four tendons. In the right foot, a separated muscle belly for the fifth toe was very thin and originated from the intermuscular septum as a flat fascia under the flexor digitorum brevis. In another case (male), three heads (lateral, intermediate, and medial) formed the quadratus plantae and the lateral and intermediate heads fused with the flexor digitorum brevis. Variation of the flexor digitorum brevis may be important clinically when considering reconstruction of the heel pad by flexor digitorum brevis myocutaneous flap transfer.

To investigate the optimal repair method of a soft tissue defect of heel, the authors designed a pedicled island myocutaneous flap of the flexor digitorum brevis. From 1984 to 1997, 26 cases with soft tissue defects of the heel were accepted in a clinical trial. There were 18 males and 8 females ranging in age from 15 to 60 years. The defects ranged from 2.5 by 1.5 cm to 8.0 by 6.0 cm. After operation, all of the flaps survived. The patients were followed for 9 to 72 months. All but one of the flaps had primary healing; in that one, there was infection of the periphery of the flap. The contour of the heels was deemed satisfactory, flap sensation was good, and the weight-bearing function was successful. The authors concluded that the myocutaneous flap of the flexor digitorum brevis could be used to repair soft tissue defects of the heel because of its nearby position, hidden donor site, good recovery of skin sensation, and weight-bearing function. The procedure is simple, and there is little associated morbidity. However, because of the limited donor area, the preoperative design must be planned carefully.
ANATOMIC LANDMARKS

**Landmarks**

The abductor hallucis is an intrinsic motor of the medial side of the foot, arising from the calcaneus medially and inserting onto the base of proximal phalanx of the great toe.

**Size**

10 × 3 cm.

**Origin**

Medial border of the calcaneus and plantar aponeurosis.

**Insertion**

Base of the proximal phalanx of the great toe.

**Function**

Great toe abduction and medial support of the longitudinal arch of the foot.

**Composition**

Muscle.

**Flap Type**

Type II.

**Dominant Pedicle**

Medial plantar artery.

**Minor Pedicle**

Two or three distal muscular perforators.

**Nerve Supply**

Medial plantar nerve L4-L5.
Section 14C

FOOT

Abductor Hallucis Flap

CLINICAL APPLICATIONS

Regional Use

Medial ankle and posterior plantar foot
ANATOMY OF THE ABDUCTOR HALLUCIS FLAP

**Fig. 14C-1**

**Dominant pedicle:** Proximal branch of medial plantar artery
ANATOMY

Landmarks The abductor hallucis is an intrinsic motor of the medial side of the foot. It arises from the calcaneus medially as a fusiform muscle belly, tapering to a long, tendinous insertion one half to two thirds of the way along its course to the great toe.

Composition Muscle. It can be used as a myocutaneous variant.

Size 10 × 3 cm.

Origin Medial border of the calcaneus and plantar aponeurosis.

Insertion Medial base of the proximal phalanx of the great toe.

Function Great toe abduction and medial support of the longitudinal arch of the foot.

Arterial Anatomy (Type II)

Dominant Pedicle Proximal branch of the medial plantar artery

Regional Source Posterior tibial vessels.

Length 2 cm.

Diameter 0.6 mm.

Location The vessel enters the proximal third of the muscle on its deep surface.

Minor Pedicle Two or three distal muscle perforators arising from the medial plantar artery

Regional Source Posterior tibial vessels.

Length 1 to 2 cm.

Diameter 0.5 mm.

Location Central third of the muscle.

Venous Anatomy

Venous drainage follows the arterial supply draining into the posterior tibial venous outflow.

Nerve Supply

Motor Medial plantar nerve branch enters the muscle on its medial deep surface adjacent to the dominant vascular pedicle.

Sensory This nerve is derived from the medial plantar nerve L4-L5, following the course of the medial plantar artery, and supplies sensation to the skin overlying the muscle belly.
**Vascular Anatomy of the Abductor Hallucis Flap**

**Fig. 14C-2**

**Dominant pedicle:** Proximal branch of medial plantar artery (*D*)

**Minor pedicle:** Two or three muscular branches of medial plantar artery (*m*)

*e,* Medial plantar artery
Deep surface of intrinsic foot muscles

**Fig. 14C-2**

**Dominant pedicle**: Proximal branch of medial plantar artery (D)

**Minor pedicle**: Two or three muscular branches of medial plantar artery (m)

d, Abductor digiti minimi; e, medial plantar artery; f, flexor digitorum brevis; h, abductor hallucis; pt, posterior tibial; t, lateral plantar artery
**FLAP HARVEST**

**Design and Markings**

The medial border of the calcaneus and the base of the great toe are marked, and the muscle follows a line drawn between these two points within the medial instep. A skin island approximately 3 by 10 cm may be raised and is usually designed as a V-Y advancement to be used for coverage over the first metatarsal head.

![Marking for incision for muscle flap elevation](image)

![V-Y advancement flap skin island design](image)

*Fig. 14C-3*

**Patient Positioning**

The patient is placed either in the prone or lateral decubitus position, and a tourniquet is used for dissection.
GUIDE TO FLAP DISSECTION

Standard Muscle Flap

A linear medial plantar incision is made over the muscle belly, and dissection is taken down through the plantar fascia and aponeurosis until the muscle belly is identified proximally. The distal tendon insertion can be divided medial or proximal to the metatarsophalangeal joint. The muscle is then raised from distal to proximal, dividing minor pedicles as they are encountered in the midportion of the muscle. Proximal dissection will expose the flexor hallucis longus muscle deep to the abductor. The dominant vascular pedicle entering the deep lateral surface of the muscle is preserved with any nerve fibers as needed. The flap is then ready for transposition into an adjacent wound.

FLAP VARIANTS

- Standard myocutaneous flap
- Myocutaneous reverse V-Y flap
Standard Myocutaneous Flap
The flap is raised in standard fashion while incorporating non-weight-bearing skin on the instep. It can be raised with a medial plantar flap, as described in Chapter 14F.

Myocutaneous Reverse V-Y Flap
A V-Y skin island is designed with its base distal, centered over the long axis of the muscle. Flap dissection then proceeds as with the standard muscle flap while preserving the minor pedicles in the midportion of the dissection. Proximal dissection also preserves the medial plantar artery and while protecting this structure, the origin can be safely divided. This allows distal translocation of the flap into a defect, at the base of the great toe, for example.

Fig. 14C-5

V-Y advancement to distal foot
ARC OF ROTATION

Standard Flap
Based on its proximal blood supply and attachment, the flap will rotate 90 degrees to cover medial ankle wounds.

Reverse Flap
The flap can be advanced distally to the first metatarsal head as a V-Y flap based on the distal blood supply.
FLAP TRANSFER
The reverse V-Y flap is simply advanced into the distal defect. The standard flap can either be rotated into the defect by dividing a skin bridge, or, if tension is not too great, it can be tunneled into a medial defect.

FLAP INSET
The flaps are sutured in with nonabsorbable cutaneous sutures for a V-Y skin island and absorbable deep sutures for a standard muscle flap. In a standard muscle flap, a skin graft is applied to the muscle belly for coverage.

DONOR SITE CLOSURE
The standard flap donor site is closed with simple skin stitches; the V-Y flap is converted to a Y closure, again with cutaneous sutures.
CLINICAL APPLICATIONS

This 47-year-old man sustained a crush injury to his hindfoot 3 years before this presentation. One year before this presentation, calcaneal osteomyelitis was managed with resection of sequestra and coverage with a gracilis muscle flap and skin graft. He now had clinical evidence of tibial nerve compression within the tarsal tunnel. Following resection of the scar and neurolysis of the tibial nerve soft tissue, an abductor hallucis muscle flap and skin graft were used to cover the nerve.

Fig. 14C-8  A, Following neurolysis of the tibial nerve posterior to the medial malleolus, the abductor hallucis muscle was elevated as described. B, The muscle flap was transposed without dividing the muscle’s origin and easily covered the tibial nerve. C and D, The patient is shown 3 months postoperatively. (Case courtesy Lawrence Colen, MD.)
This 19-year-old man presented with a fourth-degree burn of the medial hindfoot after a motorcycle accident. Soft tissue was debrided, and the medial calcaneus was burred. The wound was closed with an abductor hallucis muscle flap transfer and skin graft. Additional skin graft was used to repair areas of deep partial-thickness injury.

Fig. 14C-9  A and B, Fourth-degree burn of the medial hindfoot. C, The course of the abductor hallucis muscle belly was outlined. D, The patient is shown after debridement, abductor hallucis muscle flap transposition, and skin grafting. (Case courtesy Lawrence Colen, MD.)
Pearls and Pitfalls

- A tourniquet is used for all flap dissection to avoid pedicle damage.
- Posterior tibial inflow should be evaluated clinically, and with ultrasound or arteriography if necessary, to confirm adequate flow to the flap.
- The flap itself is small and unsuitable for coverage of large medial ankle defects.
- When a larger area of coverage is required, the effective flap surface can be enhanced by incorporating the medial plantar flap in the design.

EXPERT COMMENTARY
Lawrence Colen

Anatomic Considerations
In many respects, the planning involved in transferring the abductor hallucis muscle flap is very similar to that required for the flexor digitorum brevis muscle. This flap is even smaller than the flexor digitorum brevis (see Section 14B), and in some cases has very little muscle associated with its distal half, where it may be primarily tendon in nature. As with the flexor digitorum brevis, the blood supply from the medial plantar artery requires antegrade blood flow in the posterior tibial artery to ensure a successful transfer.

The vascular evaluation performed for this flap should be the same as that described for the flexor digitorum brevis muscle. Despite these concerns, I have found the abductor hallucis muscle flap to be useful for complex wounds about the medial ankle and heel. Flap elevation is very straightforward, and, when the flap is positioned in the recipient site with the deep surface of the muscle placed superficially, the skin graft “takes” over the muscle without incident.

A myocutaneous variant of this flap that I have never used is described in the text. In the early to mid-1980s, under the guidance of Dr. Mathes, we investigated the blood supply to the plantar skin. We found that there are enough cutaneous perforators coursing through the plantar fascia to the overlying skin to permit the V-Y advancement of plantar skin and fascia, without the need to use the abductor hallucis muscle at all. Two-centimeter wounds over the first metatarsal head may therefore be closed with a plantar V-Y advancement flap, without underlying muscle manipulation.

Recommendations
Technique
The flap is dissected with the patient in the prone position, with a well-padded tourniquet in place over the distal thigh. As with all other foot and ankle procedures that we do, if the patient has had a recent vascular surgical intervention, such as a bypass graft or transluminal angioplasty, I avoid using the tourniquet. Instead, I secure an Esmarch bandage to the distal leg to perform a limited exsanguination of the operative site. I make my skin incision a bit more medially than is depicted in this section, usually at the junction of the glabrous medial plantar skin and the nonglabrous instep area, curving laterally toward the muscle’s origin from the medial border of the calcaneus. The skin may then be elevated off of the superficial surface of the abductor hallucis muscle until the entire muscle and its distal tendon are exposed.

Continued
The blood supply to the muscle is from small branches of the medial plantar artery, which course in the cleft between the flexor digitorum brevis and abductor hallucis muscles. The muscle flap is elevated from distal to proximal, with division of the small distal vascular pedicles from the medial plantar artery. The most important blood supply to this muscle comes from branches from the most proximal portions of the medial plantar artery, within the tarsal tunnel, so the distal pedicles can be divided without concern.

It is often not necessary to divide the origin of the muscle from the calcaneus, but this certainly can be done to improve flap rotation and inset. If the origin is divided, care is taken to protect the proximal blood supply to the muscle. The flap is inset with its deep surface placed superficially, and a skin graft is applied. One can use the distal tendinous portion for flap inset by placing sutures from the tendon to the distalmost aspects of the defect to be closed. The donor site is closed over a small suction drain that is left in place for 2 to 5 days.

Postoperative Care
Like most of my foot and ankle repairs, the limb is immobilized in a well-padded short-leg splint, and the patient is kept on bed rest or wheelchair-only ambulation to avoid postoperative swelling. The graft is inspected on postoperative day 5. If healing is progressing well, then non-weight-bearing ambulation with Ace wrap support may be started.

Complications: Avoidance and Treatment
The most common complication is partial skin graft loss, which is generally treated with local wound care until healed. Trimming some of the tendon from the flap at the time of skin graft placement will often prevent this complication.

Bibliography With Key Annotations

Synovial hemangioma is a rare, benign vascular tumor that arises from any synovium-lined surface. The intraarticular type is most common. The tumor forms a mass lined by synovial membrane. The authors reported a case of a juxtaarticular synovial hemangioma of the ankle.


Microsurgical free flaps became the method of choice in the late 1970s for foot and ankle reconstruction. Before this time, local muscle flaps were utilized for this purpose. The authors’ aim was to determine whether the decreased use of local muscle flaps was justified. They identified all patients who underwent foot and ankle reconstruction with either local muscle flaps or microsurgical free flaps from 1990 through 1998 in a single center. Flaps were used for defects with exposed tendons, joints, or bone. Local muscle flaps were selected over free flaps if the defect was 3 by 6 cm or smaller and within reach of the local muscle flap. Otherwise, free flaps were transferred. Wounds were located in the hindfoot, midfoot, and ankle. Both diabetic and traumatic wounds were treated. The success rate was 96%. The complication rate was 26% and included patient death, dehiscence, and partial flap or split-thickness skin graft loss. The overall limb salvage rate was 91%. Diabetes did not significantly affect healing and limb salvage rates. The authors concluded that local muscle flaps provided a simpler, less expensive, and successful alternative to microsurgical free flaps for small foot and ankle defects with exposed bone (with or without osteomyelitis), tendon, or joint at their base. Diabetes did
not adversely affect healing and limb salvage rates, but it significantly affected healing times (twofold increase), length of stay (2.7 times as long), and long-term survival (63% survival in diabetic patients versus 100% in the trauma group).


The authors performed an anatomic study of the lower limb vasculature of 50 cadavers. They found that there are six angiosomes of the foot and ankle originating from the three main arteries and their branches to the foot and ankle. Blood flow to the foot and ankle was redundant, because the three major arteries feeding the foot had multiple arterial-arterial connections. Based on these results and clinical experience, the authors concluded that, by performing a Doppler examination of these connections preoperatively, it is possible to quickly map the existing vascular tree and the direction of flow.


The aim of this study was to compare the effectiveness of pedicled muscle flaps with that of microsurgical free flaps in diabetic patients with complex foot and ankle reconstruction. The authors reviewed the Georgetown Wound Registry to identify all patients who underwent pedicled muscle flap or free flap reconstruction from 1990 to 2000. The follow-up period was 8.1 ± 3.1 years. Thirty-eight diabetic and 42 nondiabetic patients were identified. Flap coverage was used for defects with exposed tendons, joints, or bone. Pedicled muscle flaps were chosen for smaller defects. Thirty-two patients received 34 pedicled muscle flaps for 34 wounds, with the following results: 91% success rate, 94% limb salvage rate, 78% patient survival rate, and a 33% complication rate. Forty-eight patients received 52 free flaps for 51 wounds, with the following results: 94% healing rate, 96% limb salvage rate, 77% patient survival rate, and an 18% complication rate. Diabetes did not apparently affect the success of pedicled muscle flap or free flap reconstruction. It did, however, increase the number of debridements, lengthen healing times, and decrease long-term survival. The authors concluded that pedicled muscle flaps were as effective as free flaps for covering small complex foot and ankle defects, despite the complication rate.


The most common options available for reconstruction of the foot were reviewed. The foot comprises four different anatomic and functional areas. Planning and final outcomes are based on the type of flap available for a specific defect in one of these four territories.


Defects of the medial ankle and foot are challenging for reconstructive surgeons. The abductor hallucis muscle flap is not commonly employed for this purpose, with only a few well-documented cases published. The authors reported on a series of four patients who underwent reconstruction of foot and ankle defects with the abductor hallucis muscle flap. In two cases, the flap was transposed in combination with a medialis pedis flap to cover a medial ankle defect. In the third patient, it was combined with a medial plantar flap. The muscle flap filled calcaneal dead space after osteomyelitis debridement, and the cutaneous flap replaced debrided skin at the heel. In the fourth patient, the abductor hallucis flap was used as a distally based turnover flap to cover a large forefoot. The follow-up ranged from 18 to 64 months. In the early postoperative period, two flaps had marginal flap necrosis and were skin grafted. In all cases protective sensation of the skin was satisfactory as early as 6 months. All patients were fully mobile as early as 3 months after treatment. At 43.3 months, all flaps provided durable coverage. There were no functional gait deficits and no donor site complications.
ANATOMIC LANDMARKS

Landmarks
Thin, relatively hairless skin island from the dorsum of the foot. The flap extends from the ankle proximally to the base of the toes distally and occupies the medial two thirds of the dorsum of the foot.

Size
6 × 10 cm.

Composition
Fasciocutaneous.

Flap Type
Type B.

Dominant Pedicle
Dorsalis pedis artery.

Nerve Supply
Superficial and deep peroneal nerves, L4 to S1.
Section 14D

FOOT

Dorsalis Pedis Flap

CLINICAL APPLICATIONS

Regional Use
- Distal leg
- Ankle
- Foot

Distant Use
- Head and neck
- Upper extremity

Specialized Use
- Vascularized bone, joint, tendon
ANATOMY OF THE DORSALIS PEDIS FLAP

Arterial supply to flap

Venous supply to flap

Nerve supply to flap

Fig. 14D-1

Dominant pedicle: Dorsalis pedis artery
**ANATOMY**

**Landmarks**
Thin, relatively hairless skin island from the dorsum of the foot based on the dorsalis pedis axial blood supply. The flap extends from the ankle proximally to the base of the toes distally and occupies the medial two thirds of the dorsum of the foot.

**Composition**
Fasciocutaneous.

**Size**
$6 \times 10 \text{ cm}$.  

**Arterial Anatomy (Type B)**

**Dominant Pedicle**  
*Dorsalis pedis artery*

**REGIONAL SOURCE**
Anterior tibial artery.

**LENGTH**
First dorsal metatarsal artery, 5 cm; dorsalis pedis artery, 4 to 6 cm; distal anterior tibial artery can add another 5 to 10 cm.

**DIAMETER**
2 to 3 mm proximally, with the first dorsal metatarsal artery at 1.1 mm.

**LOCATION**
Flap is supplied by septocutaneous perforators arising from the dorsalis pedis artery, which is the termination of the anterior tibial artery. The anterior tibial artery courses over the anterior aspect of the ankle joint emerging from beneath the extensor retinaculum as the dorsalis pedis artery. At this point it lies between extensor hallucis longus medially and extensor digitorum longus laterally. Distally it passes beneath the extensor digitorum brevis tendon slip to the great toe, which it supplies through the lateral tarsal artery. Between the bases of the first and second metatarsals, it splits into the first dorsal metatarsal artery and the deep plantar artery. The first dorsal metatarsal artery courses distally in the first interosseous space to supply digital branches to the lateral side of the great toe and medial side of the second toe. The course and branching patterns of the vessel can be variable. It usually lies superficial to the first dorsal interosseous muscle but may lie deep to it. At the level of the metatarsal heads, it gives rise to the distal communicating branch, which dives deep between the metatarsal heads to communicate with the first plantar metatarsal artery. It may be absent in up to 14% of individuals.

**Variations of the Dorsalis Pedis Artery**
83% of cases arise from the anterior tibial artery; 17% arise from atypical locations (types A-D)

**TYPE A**
3% arise from the perforating peroneal artery.

**TYPE B**
In 1.5% of cases the anterior tibial artery deviates laterally to the position of the peroneal artery.

**TYPE C**
In 0.5% of cases the vessel arises from a confluence of the anterior tibial and perforating peroneal arteries.

**TYPE D**
In 12% of cases the vessel is effectively absent.

**Variations of the First Dorsal Metatarsal Artery**

**TYPE A (SUPERFICIAL)**
In 50% of cases the artery lies superficial to the first dorsal interosseous muscle.

**TYPE B**
In 40% of cases the vessel arises from the deep perforating artery lying deep to or within the first interosseous muscle, becoming superficial between the heads of the first and second metatarsals.

**TYPE C**
In 10% of cases the vessel may disappear almost completely; the blood flow of the great and second toes is dependent on the plantar metatarsal artery.

**Venous Anatomy**

The venous drainage of the flap consists of superficial and deep systems. The deep system is composed of paired venae comitantes following the dorsalis pedis artery to drain into the anterior tibial venae comitantes. These are not typically used as the venous outflow of the flap. The superficial
venous system arises from the dorsal venous arch, located in the subcutaneous tissues of the distal foot. These drain into medial and lateral veins; the medial one becomes the saphenous vein over the medial malleolus. This vessel usually serves as a more reliable venous outflow tract for the flap.

**Nerve Supply**

**Sensory**

Arises from the superficial and deep peroneal nerves. The deep branch (L4–L5) supplies a small area over the dorsal first web space. The superficial nerve (L4 to S1) supplies most of the medial dorsum of the foot. The superficial peroneal nerve passes between the extensor digitorum longus and the peroneus brevis muscle before dividing below the extensor retinaculum into its medial and dorsal branches. These lie within the substance of the flap and can provide sensibility. By contrast, the deep peroneal nerve follows the course of the anterior tibial artery deep to the extensor retinaculum at which point it divides into medial and lateral branches. The medial branch follows the dorsalis pedis artery and then the first dorsal metatarsal artery, ultimately supplying the first web space. It should be preserved within the foot and not raised with the flap.

**Vascular Anatomy of the Dorsalis Pedis Flap**

![Dorsalis Pedis Flap](image.png)

**Fig. 14D-2**

**Dominant pedicle:** Dorsalis pedis artery *(D)*
Dominant pedicle: Dorsalis pedis artery (D)
FLAP HARVEST
Design and Markings
The flap is designed on the medial aspect of the dorsum of the foot. The skin island is approximately 8 by 10 cm, and the distal tip becomes less reliable because of the smaller size of the perforators.

Patient Positioning
The patient is placed in the supine position with a tourniquet on the thigh. Before the leg is prepared and draped, the foot is allowed to dangle to fill the superficial veins; this allows accurate marking of the largest draining veins medially. All surgical dissection, however, is done under tourniquet control.

GUIDE TO FLAP DISSECTION
Standard Flap
The distal incision is made first to identify the first dorsal metatarsal artery for retrograde dissection.

Fig. 14D-4  A, Outline of the dorsalis pedis flap, whose central axis lies along the second metatarsal bone. Note that flap elevation begins by incising the distal margin and locating the first dorsal metatarsal artery. Dissection proceeds proximally deep to the first dorsal metatarsal artery.
The deep peroneal nerve is identified within the first web space as are the branches of the superficial peroneal nerve in the second, third, and fourth spaces. Assuming the most common anatomic variation, the dissection is carried out just deep to the first dorsal metatarsal artery overlying the belly of the first interosseous muscle. The plane of dissection is deep to the extensor hallucis brevis tendon, superficial to the peritenon of the extensor brevis tendons. Maintenance of this tendon coverage is important to achieve a stable skin graft on the donor site, which can otherwise be problematic. The tendon of extensor hallucis brevis is raised with the flap and can either be incorporated or discarded subsequent to complete elevation of the dorsalis pedis artery.

Dissection continues to the base of the metatarsal at which point the deep perforating branch of the dorsalis pedis artery is encountered. The skin incision is then carried up medially to identify and dissect the greater saphenous vein draining the dorsal venous arch of the flap. The vascular anatomy at the confluence of the first dorsal metatarsal artery and the deep perforating artery with the dorsalis pedis artery must be clearly identified.

![Diagram](image-url)
The deep perforating branch can then be safely divided. The lateral skin incision is then completed, converting the flap to a true island based on the dorsalis pedis vessels. To lengthen the pedicle, the extensor retinaculum is divided anteriorly, and proximal dissection, including part of the distal anterior tibial artery, can be completed based on pedicle length requirements.

The extensor hallucis tendon, which has been raised with the flap to this point, is divided superolaterally where it crosses the extensor digitorum longus tendon to the second toe. This tendon can either be ignored or may be incorporated as a tendon graft when the flap is used for reconstruction of the hand.

Fig. 14D-4  D, The flap, now elevated, is attached only to the anterior tibial artery and its vena comitans, the greater saphenous vein, and the superficial peroneal nerve branches.

FLAP VARIANTS

- Tendinocutaneous flap
- Sensory flap
- Osteocutaneous flap
- Distally based reverse flow flap
Tendinocutaneous Flap
As described earlier, the tendon of the extensor hallucis brevis is routinely raised with the flap. This can be used as a single or split tendon graft to bridge a tendon gap, most commonly on the dorsum of the hand. If more tendons are required, several components of the extensor digitorum longus can be included. This allows reconstruction of all of the extensor tendons on the back of the hand.

Sensory Flap
The sensory flap involves an identical dissection to the standard flap, but particular care is taken to dissect and preserve the main trunk of the superficial peroneal nerve proximally for the required length.
Osteocutaneous Flap
The skin flap for this procedure is often smaller than the traditional dissection described previously. It is centered over the second metatarsal. The perforating branches from the dorsal metatarsal artery penetrate the bone medially, providing 6 to 8 cm of vascularized bone, depending on the patient’s foot size. The distal and medial incisions are made, and the first dorsal interosseous muscle and its distal communicating branch are identified. The tendon of the extensor hallucis brevis is detached as described previously. The first dorsal metatarsal artery is elevated to include all of the medial portion of the dorsal interosseous muscle between it and the shaft of the second metatarsal. This maneuver preserves the perforators to the bone. The lateral incision is then made, preserving the dorsal venous arch. Dissection is carried medially over the third metatarsal, and the extensor tendons to the second toe are divided. The deep transverse metatarsal ligament is divided between the second and third and second and great toes to allow mobilization of the second metatarsal bone. Dissection is then continued proximally, as originally described, to harvest the pedicle. The capsule of the second metatarsophalangeal joint can be opened to mobilize the distal end of the second metatarsal. The proximal end of the metatarsal is divided through metaphysis. Alternatively, if the metatarsophalangeal joint is required in the reconstruction, the joint capsule is left intact, and a distal osteotomy can be made through the diaphysis of the proximal phalanx.

**Fig. 14D-7**

[A] Flap design  
[B] Elevation of flap
Distally Based Reverse Flow Flap
The reverse flow flap is based on the deep perforating vessel and can be used to cover very distal amputation wounds. Dissection starts proximally in this case, identifying the dorsalis pedis artery beneath the extensor retinaculum. Dissection is carried distally to the bifurcation of the dorsalis pedis artery into the deep perforating plantar branch and the more superficial first dorsal metatarsal artery. The dorsalis pedis artery is occluded with a vascular clip for 15 to 20 minutes to assess the adequacy of circulation from the plantar inflow. If the flap does not become congested, the dorsalis pedis artery can be ligated and the distally based flap raised.

Fig. 14D-8  Similar to the dorsal metacarpal artery flap in the hand, a reverse flow flap can be based on the dorsalis pedis–dorsal metatarsal vessels and their interconnection with the deep plantar artery.
**ARC OF ROTATION**

**Standard Flap**
The standard flap will reach the distal leg or malleoli. However, it is most commonly used for microsurgical transplantation to the head and neck or upper extremity.

![Arc to ankle](Fig. 14D-9)

**Distally Based Reverse Flow Flap**
The reverse flow flap is based on the perforating branch communicating with the deep plantar arch. This pedicled variant will reach the medial side of the great toe or the end of the distal foot amputation.

![Arc to distal foot](Fig. 14D-10)
FLAP TRANSFER
A pedicled flap is simply transposed, taking care not to kink the pedicle. It is difficult to pass this flap through a subcutaneous tunnel in the ankle; it is far safer to split any intervening skin bridge and simply skin graft the pedicle rather than risk compression. Free flap transfer is performed in a standard manner, with recipient vessels based entirely on the location and nature of the defect being treated.

FLAP INSET
The flap is sewn in place using a two-layer closure. If tendon grafts or vascularized bone and/or joint have been included, these will be fixed in place with K-wires or plates and screws before vascular anastomosis and soft tissue closure are performed.

DONOR SITE CLOSURE
For most flaps, primary donor site closure is not possible. A split-thickness skin graft is almost always required, and it is imperative to provide not only a well-vascularized recipient bed but also an excellent graft-to-bed apposition. A well-vascularized recipient bed is completely contingent on preservation of peritenon on the extensor tendons on the dorsum of the foot.

CLINICAL APPLICATIONS
This 78-year-old woman was referred with an exposed fibular bone above the malleolus after removal of an infected plate and screws at the site of a fracture. After two debridements, a pedicled dorsalis pedis flap was used to close the defect. Both the dorsalis pedis and posterior tibial artery vessels were palpable, but there was considerable fibrosis in the region of the dorsalis pedis.

Fig. 14D-11  A, Lateral malleolar defect closed by pedicled dorsalis pedis flap. The flap was sited to span possible perforators proximal and distal to the belly and tendon of the extensor hallucis brevis from the dorsalis pedis artery and dorsal metatarsal arteries, respectively. B, Designing the length of the pedicle. C, Immediate postoperative result. D, The reconstructed site is seen 10 days postoperatively. There is superficial blistering of the flap; the graft site is healing well. This is probably the most favorable site and size for minimal morbidity from the dorsalis pedis flap. (Case courtesy Wayne A. Morrison, MD.)
This 29-year-old man presented with a traumatic defect of the posterior aspect of the heel at the junction of the weight-bearing heel pad and the posterior calcaneus. The defect was initially skin grafted, but hyperkeratosis at the skin graft margins developed and became intractable. The graft was excised and the defect closed with a free dorsalis pedis flap from the opposite foot. Note that the pedicled flap will not reach to this site.

Fig. 14D-12  A, Posterior heel-Achilles defect. B, A free dorsalis pedis flap was transferred from the opposite foot. C, Immediate postoperative result. D and E, The patient’s heel is seen 2 years postoperatively. Note the ideal, adherent thin skin, and the acceptable size and site of secondary defect on the donor foot, with minimal morbidity. (Case courtesy Wayne A. Morrison, MD.)
This 64-year-old man had undergone a maxillectomy for squamous cell cancer 8 years earlier. He was free of disease but was having difficulty with oral competence and nasal regurgitation while wearing his obturator. He underwent maxillary reconstruction with a dorsalis pedis free flap with an accompanying second metatarsal. The skin paddle provided both palate and nasal floor reconstruction, supported by the metatarsal bone.

Fig. 14D-13  A, Preoperative view of the patient's maxillary defect. The lip segment was free floating, without support. B, The flap design was centered over the dorsalis pedis artery and included the saphenous vein. C, The elevated and skin paddle are shown. D, The flap's undersurface with the second metatarsal. E, The inset flap; the reconstructed palate can be seen. The lip segment was inset into a deepithelialized strip of the skin paddle. Osteosynthesis of the metatarsal was performed to the neighboring zygoma bilaterally. F, The donor site was closed with an amputation of the second toe and closure as in a ray section. The superficial wound was closed. The flap reconstruction healed well, and the patient was able to speak and eat without an obturator. The donor site had some breakdown, requiring prolonged dressing changes. Donor site issues represent the biggest drawback to the use of this flap. (Case supplied by MRZ.)
PEARLS AND PITFALLS

- The surgeon must be well aware of the vascular variants associated with this flap.
- If a reverse flap is attempted, the adequacy of the plantar inflow must be established before proximal division of the dorsalis pedis artery.
- Adequate dorsal venous outflow is best achieved by incorporating the saphenous circulation.
- Severe donor site morbidity can complicate the harvest of this flap. It is absolutely essential to preserve the peritenon overlying the extensor tendons on the dorsum of the foot.
- The deep peroneal nerve to the first web space must be preserved to maintain normal sensibility to the great toe.

EXPERT COMMENTARY
Wayne A. Morrison, Edwin J. Morrison

The dorsalis pedis flap from the dorsum of the foot was one of the earliest free flaps described. Familiarity with the dorsalis pedis artery in the context of toe transfers probably led, in part, to its early realization. Because of its thinness and pliability, it found immediate application in facial and intraoral reconstruction. It also offered an elegant reconstructive option as a local pedicle flap for defects in the ankle and posterior heel, which were previously problematic when reconstructed with local flaps.

ANATOMIC CONSIDERATIONS

After description of the radial artery forearm flap and its gradual acceptance, the popularity of the dorsalis pedis flap quickly faded because of the limited area available and frequent healing problems in the foot. Vascularity was also somewhat capricious, because although the dorsalis pedis artery itself was simple to dissect, the actual sites of its connections into the overlying skin have always been obscure. Conflicting studies put the maximum density of perforators either just proximal or distal to the avascular zone, where the extensor hallucis brevis muscle and tendon cross the artery. In surgery as in life, once bitten twice shy—and early flap losses or protracted foot healing soured many investigators, causing them to retreat to the safer route of the radial forearm flap. For the most part, the forearm flap is a better and safer option, particularly for head and neck and hand surgery, where thin flaps are required.

But reconstructing like with like is always the aim, and the skin cover of the dorsal foot ideally matches that of the ankle, posterior heel, and Achilles region. Dorsal foot skin is unique in that both the skin and subcutis are firm and fibrous and densely adherent to underlying bone and fascia, anchored by collagenous ligamentous filaments designed to prevent shear. This contrasts markedly with the radial forearm flap, which is floppy and less durable.

INDICATIONS

If morbidity can be minimized, the rightful and continuing place for the dorsalis pedis flap is in resurfacing of ankle and posterior heel skin defects. Fortunately, in most cases, this
can be achieved as a pedicled flap, even retaining in some cases superficial peroneal nerve branches for innervation. However, the artery is too short to reach the tip of the heel without an intervening vein graft. When the flap is not available because of associated injury or absent vessels, a free flap from the opposite foot can be considered.

Advantages and Disadvantages

An attraction of the dorsalis pedis flap is its capacity to be combined with other vascularized tissue components, such as bone (the second metatarsal) and extensor tendons, or as a separate skin island in continuity with the vascular pedicle supplying the toe or toe segments for skin cover of the toe inset in the hand.

However, just because these composite anatomic procedures can be performed does not mean that they should always be performed. Foot morbidity is the overriding concern, and in many cases, nonvascularized bone and tendons from other sources will achieve the same result with less morbidity. Some guiding principles include the following:

- The foot and lower leg are notorious for slow healing, so in principle, donor sites from the upper limb are preferable.
- Only small flaps should be considered, not more than 5 cm in diameter. Flaps too large risk chronic ulceration, tendon loss, pain and difficulty with footwear.
- Flaps that are too distal result in verrucous lymphedematous skin change in the webs and proximal toes from chronic lymphatic and venous insufficiency. For the same reason, dorsal skin should never be taken in continuity with toes to facilitate cover in the hand. Separate, more proximal islands on the same dorsalis pedis pedicle are permissible.
- Paratenon loss over the extensors, especially the extensor hallucis longus tendon, leads to graft failure and tendon exposure.
- Chronic wear and tear of the graft overlying the extensor hallucis longus may lead to problems with footwear.
- Neuromata of the superficial peroneal nerve stumps are not uncommon.
- Flap elevation sacrifices a major foot vessel. Despite this, the flap may not be adequately vascularized on the dorsalis pedis pedicle, and the site of maximum vascularization is debated. It is generally felt that the maximum vascularization to the skin is just distal to the extensor hallucis brevis tendon at the site of origin of the dorsal–metatarsal artery, where the dorsalis pedis penetrates deeply into the foot between the first and second metatarsals. Flaps should therefore be sited over this point and include the dorsal–metatarsal artery. If this is deeply situated, the proximal contents of the intermetatarsal space should be included with the flap. If no dorsal metatarsal artery can be heard with a Doppler probe, the flap should be designed more proximally or is best avoided. The surgeon must ensure that the dorsalis pedis artery is not sited laterally in the foot, where it derives from the peroneal system. In these cases, the use of a dorsalis pedis flap is unwise.
- Multiple significant arterial branches must be ligated from the proximal dorsalis pedis and distal anterior tibial artery system to enable maximum mobilization of the pedicle for a posterior heel defect. Despite this, the arterial pedicle will not allow the flap to reach the heel tip, and a graft will be required. Rather than attempting this and sacrificing important malleolar branches, the surgeon should accept the need for a short vein graft for heel tip defects.

Continued
References


Bibliography With Key Annotations


The authors reported results in 12 patients treated with “completely vascularized single-stage approaches,” so defined because skin, tendon, and nerve were transferred as a compound flap, and all were vascularized. A free dorsalis pedis cutaneotendinous flap was used in 7 patients, and a radial forearm cutaneotendinous island flap was transposed in 5 patients. A dorsalis pedis flap provides four vascularized extensor tendons (extensor digitorum communis tendons), and the radial artery flap permits the inclusion of one completely vascularized tendon (palmaris longus) and two “strips” of vascularized tendons (flexor carpi radialis and brachioradialis). The flaps survived in all cases, and the transferred tendons were functioning well. The dorsalis pedis flap can be employed in the reconstruction of cutaneotendinous defects of the dorsum of the hand that require the use of three or four tendons grafts. The authors suggested the use of forearm cutaneotendinous flaps in cases of reconstruction of one or two extensor tendons. The completely vascularized single-stage reconstruction avoids prolonged hospitalization and results in a rapid restoration of near-normal function and appearance of the hand.


Ian Taylor introduced the angiosome concept, separating the body into distinct three-dimensional blocks of tissue fed by source arteries. Understanding the angiosomes of the foot and ankle and the interaction among their source arteries is clinically useful in surgery of the foot and ankle, especially in the presence of peripheral vascular disease. In 50 cadaver dissections of the lower extremity, arteries were injected with methylmethacrylate in different colors and were dissected. The authors reported their clinical experience; preoperatively, each reconstructive patient’s vascular anatomy was analyzed using Doppler ultrasound and the results were evaluated. There are six angiosomes of the foot and ankle originating from the three main arteries and their branches to the foot and ankle. The three branches of the posterior tibial artery each supply distinct portions of the plantar foot. The two branches of the peroneal artery supply the anterolateral portion of the ankle and rear foot. The anterior tibial artery supplies the anterior ankle, and its continuation, the dorsalis pedis artery, supplies the dorsum of the foot. Blood flow to the foot and ankle is redundant, because the three major arteries feeding the foot have multiple arterial-arterial connections. By selectively performing a Doppler examination of these connections, it is possible to quickly map the existing vascular tree and the direction of flow.

The authors presented a case of reconstruction after first metacarpal resection with a reversed free vascularized osteocutaneous pedis flap. With this procedure, bone resorption is avoided and the trapeziometacarpal joint is preserved, in contrast to a conventional bone graft. A double rotation is applied to the flap: the head of the metatarsal becomes proximal and the palmar side becomes dorsal. The metacarpophalangeal joint undergoes arthrodesis. With a 3-year follow-up, there was no pain, the Kapandji score was 8/10 (a very good range of motion), and no osteoarthritis was noted.


Soft tissue defects of the great toe that include exposed tendon and bone present a reconstructive challenge for plastic surgeons. This study investigated the feasibility and reliability of reverse first dorsal metatarsal artery flap (FDMA) for reconstruction of the dorsal great toe soft tissue defects. Six male patients with dorsal great toe defects (mean 2.2 by 4.7 cm) underwent reconstruction using the reverse FDMA flap. Preoperative angiography was performed to confirm the existence and patency of the distal communicating artery between the FDMA and plantar metatarsal artery. The flap was raised by dividing the dorsalis pedis artery and proximal communicating arteries and rotated 180 degrees to cover the defect. All flaps survived completely. Mean follow-up time was 3.3 months. Painless full range of motion was recovered, and the contour of the flap was satisfactory. All patients returned to their normal walking and running activities and none necessitated special footwear. No donor site morbidity was encountered.


Thirty cadaver lower limbs were dissected to describe the relationship of the deep fibular nerve to the dorsalis pedis artery in the anterior tarsal tunnel and on the dorsum of the foot. The anterior tarsal tunnel is a flattened space between the inferior extensor retinaculum and the fascia overlying the talus and navicular. The deep fibular nerve and its branches pass longitudinally through this fibroosseous tunnel, deep to the tendons of the extensor hallucis longus and extensor digitorum longus. Four distinct relationships of the deep fibular nerve to the dorsalis pedis artery were determined. The dorsalis pedis neurovascular island flap contains both the dorsalis pedis artery and the deep fibular nerve. Because the design of a neurovascular free flap requires detailed knowledge of the nerve and vascular supply, the data presented were intended to help surgeons during surgical approaches to the foot and ankle.


The dorsalis pedis flap has demonstrated considerable versatility in the reconstruction of composite soft tissue defects of the hand. It has the potential benefit of being thin and pliable, having reliable vascularity, and being relatively easy to harvest. However, the flap has been plagued by questions of its reliability and concerns over the donor site. An institutional review of dorsalis pedis free flap (DPFF) reconstructions of the hand was performed for 1996 through 2006. A modified Hallock classification scheme was used to stratify the flaps. A total of 20 DPFF reconstructions of the hand were identified. There were 14 male and 6 female patients aged 20 to 53 years. Their defects included secondary web contracture as well as primary amputations and exposed bony and tendinous structures. The flaps ranged in size from 15 cm² to 110 cm². Flap survival was 100%, except one partial flap necrosis treated with a secondary skin graft. Partial donor skin graft loss was noted in 5 patients; 3 of them required a secondary resurfacing of the donor site. Functional data on 6 of 7 patients with web space contracture reconstruction showed improvements. DPFF provides durable reconstruction for composite soft tissue defects of the hand without unduly sacrificing function or form. Donor site complications in this series were minor.

The authors introduced a new technique of one-stage reconstruction for thumb loss complicated by thumb-index finger web space contracture and to report its clinical effectiveness. They reported on 11 patients with thumb loss and contracture in the thumb-index finger web space who had a combined transplantation of free tissues to reconstruct the missing thumb and to rebuild the web space. The reconstructive procedure used the second toe and the anterolateral thigh flap in 5 patients, the second toe and the scapular flap in 2, the great toe wrap-around flap and the anterolateral thigh flap in 3, and the great toe wrap-around flap and the scapular flap in 1. The two independent free tissues were connected together by a vascular combination to form an assembly with one common vascular pedicle, which was then anastomosed to the selected vessels in the recipient hand. In this vascular series the dorsalis pedis artery and the greater saphenous vein served as the common vascular pedicle of the flap transfers and the radial artery and the cephalic vein provided the recipient vessels. The outcomes of the reconstructions were evaluated using the Michigan Hand Outcomes Questionnaire. The flaps survived completely in all patients except one. In this patient a small area in the distal part of the transplanted anterolateral thigh flap became necrotic, but healed after dressing changes without the need for further surgical intervention. A mean follow-up of 3.6 years showed a mean increase of 4.3 cm in the width of the thumb-index web space and a considerable improvement in overall hand function was noted on the Michigan Hand Outcomes Questionnaire with effect sizes of greater than 3 (large effect) in all domains.


The authors reported on bilateral three-toe transplantation in 29 cases; 22 males, and 7 females. Their ages ranged from 15 to 31. The size of their defects ranged from 18 by 8 cm to 22 by 10 cm. Along with a dorsalis pedis flap, a lateral hemipulp flap was taken from the great toe and first web space flap. The second toe was taken from one foot to reconstruct the thumb; the second and third toe from another foot was used to reconstruct two fingers. The dorsalis pedis flaps were used to cover the palm and dorsum of the hand. The lateral hemipulp flaps from the great toe and first web space flaps were used to reconstruct first web space of hand. With the 58 combined flaps, 29 thumbs and 58 fingers were reconstructed. Follow-up ranged from 1 to 8 years. All the thumbs and fingers of 29 hands were reconstructed. Their shape and function were well recovered. The authors concluded that this new surgical method is effective in preserving the function of the injured hand. The function of the injured hand can be preserved by this optimal surgical method.


Much has been reported about the early donor site morbidity associated with the dorsalis pedis flap. However, easy harvesting of the flap, reliability of vascularity, thinness, and proximity to the recipient site have encouraged surgeons to adopt the flap for reconstruction of foot and distal lower leg defects and hand reconstruction. In 14 patients, the authors described achieving satisfactory donor site healing by concomitant use of the extensor digitorum brevis muscle, based on its lateral blood supply, to cover the extensor tendons before application of the graft. Using this modification will allow surgeons to reconsider using this flap more frequently.


The treatment of electrical burn injuries in the hand is difficult and challenging, because the burn widely and deeply damages not only the skin and subcutaneous tissue, but also tendon, muscle, ligaments, and bone. Compound defects of the skin and abductor pollicis brevis tendon caused by an electrical injury were reconstructed using a free dorsalis pedis flap including the extensor hallucis brevis tendon.
This composite flap is also applicable for reconstruction of thumb abduction, although its usefulness has been reported for reconstruction of defects of the dorsal skin of the hand, including the extensor tendons. Ju J, Zhao Q, Liu Y, et al. [Repair of whole-hand destructive injury and hand degloving injury with transplant of pedis compound free flap] Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 23:1153-1156, 2009.

The authors investigated the surgical methods for and clinical efficacy of repairing a whole-hand destructive injury or a hand-degloving injury with the transplant of a pedis compound free flap. The reported on 21 patients with whole-hand destructive injuries or hand-degloving injuries, including 15 males and 6 females 18 to 45 years old. Their injuries were caused by punching machine crush in 10 cases, roller crush in 7 cases, and imprinter crush in 4 cases. The time between injury and operation was 1 to 9 hours. Eleven patients had a skin-degloving injury of the whole hand, whereas the other 10 had proximal palm injuries combined with dorsal or palmar skin and soft tissue defects. After debridement, the size of wound was 9 by 7 cm to 15 by 10 cm in the dorsal aspect and 10 by 7 cm to 6 by 10 cm in the palmar aspect. The defects were repaired by the thumbnail flap of the dorsalis pedis flap and the second toenail flap of the dorsalis pedis flap in 5 cases; the thumbnail flap of the dorsalis pedis flap and the second toe with the dorsalis pedis flap in 4 case; and bilateral second toe with the dorsalis pedis flap in 12 cases. The flap area harvested ranged from 6 by 5 cm to 16 by 11 cm. Three fingers were constructed in 2 cases and two fingers in 19 cases. Distal interphalangeal joint toe amputation was conducted in the thumbnail flap donor site, metatarsophalangeal joint toe amputation was performed in the second toenail flap donor site, and full-thickness skin grafting was conducted in the abdomen. At 7 days postoperatively, the index finger in 1 patient, repaired by the second toenail flap, developed necrosis and was amputated; 1 patient developed partial necrosis of the distal dorsalis pedis flap but recovered after dressing changes. The remaining 42 tissue flaps survived; 43 of 44 reconstructed fingers survived. All the wounds healed by first intention. Two weeks postoperatively, 2 patients had partial necrosis of the donor site flap and underwent secondary skin grafting after dressing changes, and the balance of the skin grafts survived, with all wounds healing by first intention. Nineteen cases were followed up for 6 to 36 months. The flaps of the palm and dorsum of the hand showed no swelling. The reconstructed fingers had a satisfactory appearance and performed such functions as grabbing, grasping, and nipping. The sensory grade of the flaps and the reconstructed fingers was S2 to S4. There were no obvious scar contractures on the donor site on the dorsum of the foot and obvious affects on walking.


The reconstruction of the posterior heel including a wide defect of the Achilles tendon is difficult as a result of complicated infection, deficient soft tissue for coverage, and functional aspects and defects of the tendon itself. As a single-stage procedure, various methods of tendon transfer and tendon graft have been reported, along with details of local flaps or island flaps for coverage. With advances in microsurgical techniques and subsequent refinements, several free composite flaps, including tendon, fascia, and nerve flaps, have been used to reconstruct large defects in this area without further damaging the traumatized leg. The authors reported such a single-stage reconstruction of a composite Achilles tendon defect using the extensor digitorum longus tendon of the second to fourth toe in combination with a dorsalis pedis flap innervated by the superficial peroneal nerve. The follow-up of this case has proved a satisfactory outcome to date.


Rotationplasty is a well-established procedure after total femur resection, especially in children. Rehabilitation is superior to disarticulation of the hip or hemipelvectomy because patients regain hip and knee function. A tight fit of the prosthetic shaft is essential. The pretibial area has a low physiologic resistance to pressure and shear forces, and is thus at increased risk of developing pressure-related complications. Skin defects with exposure of skeletal elements require flap coverage. The dorsalis pedis flap
is one of the surgical options available for skin coverage of the proximal anterior leg. It can be rotated to cover almost any site on the anterior aspect of the leg if the pedicle is mobilized up to the anterior tibial artery. Because donor site complications are common, there are few indications for use of this flap.


The dorsalis pedis fasciocutaneous flap has been used successfully in soft tissue reconstruction both as a pedicled and a free flap. The long-term donor site problems associated with this flap prompted the authors to evaluate the use of the dorsalis pedis fascial flap in soft tissue reconstruction. They described the results of their anatomic study and clinical series with the dorsalis pedis fascial flap both as a free and a pedicled flap. An anatomic study was performed on a fresh cadaver by injecting India ink into the anterior tibial artery, and the fascial and cutaneous staining pattern was documented. Soft tissue reconstruction was performed in six patients, using the dorsalis pedis fascial flap as a free flap in four patients and a pedicled flap in two. The donor site was closed primarily in all cases. The donor and recipient wounds healed well, with good aesthetic and functional results. There were no major complications in their series. The authors stated that the dorsalis pedis fascial flap allowed them to retain the essential benefits of the dorsalis pedis flap while avoiding donor site morbidity. It provides a useful source of vascularized fascia with a potentially long pedicle.


Reconstruction of the distal portion of the foot has always represented a difficult problem in plastic surgery. The authors reported a distally based dorsalis pedis island flap based on the first dorsal metatarsal artery, which has been successfully used to treat the distal portion of the foot in eight patients. The size of flaps ranged from 3 by 4 cm to 6 by 7 cm. In seven patients, the transferred flaps survived completely and in one flap there was superficial marginal necrosis. There was no donor site morbidity. All the patients had no difficulty in wearing shoes and were walking within 6 weeks. The authors stated that the reverse first dorsal metatarsal artery flap is a good option to reconstruct the wound of the distal foot.


From February 2001 to August 2004, the authors transplanted the pedicled free graft of second tarsometatarsal joint to repair bone defects of the first carpometacarpal joint to reconstruct tissue defects of the hand in three patients. The dorsalis pedis flap was used to repair soft tissue defects of the carpometacarpal joint and the thenar eminence in two patients. The donor site was sutured directly or covered by an intermediate-thickness skin flap. The vessel of the bone flap had a constant anatomic location, and the operative procedure was deemed easy. It had minimal effect on the donor site; the flap of dorsalis pedis was used to repair the soft tissue defect in this area. The cases were followed for 1 to 2 years. In these patients the shape of the reconstituted thumb was normal. The healing time of the clinical fracture of the first carpometacarpal joint was 2 to 3 months. The function recovery of the reconstituted thumb was satisfactory. This is an effective method for repairing bone defects of the first carpometacarpal joint with the pedicled second tarsometatarsal joint graft.


It is challenging to perform an adequate reconstruction of a postenucleation irradiated orbit in patients with retinoblastoma. Rebuilding the orbital structure, reconstruction of the eye socket, and restoration of the periorbital volume are required. The authors reviewed 12 patients with hypoplastic orbital deformities who underwent orbital osteotomy and free flap transfer. Reconstruction of the orbital cavity was achieved using a C osteotomy of the lateral portion of the orbit in mild and moderate cases, or a transverse U osteotomy of the lateral wall, roof, and floor by an intracranial approach in severe cases. Socket reconstruction and periorbital volume restoration were achieved using dorsalis pedis free flap transfer. In their experience, the combination of orbital osteotomy and free flap transfer met the multiple requirements for the anophthalmic orbital reconstruction, including both orbital bony enlargement and soft tissue restoration.

Reconstruction of severe traumatic injuries of the hand with digit loss may require multiple procedures over a prolonged period. The authors presented a clinical series of patients in which these types of injuries were reconstructed in a single operation. They described a chimeric flap based on the anterior tibial vessels. A total of three free tissue transfers included an anterior tibial flap, a dorsalis pedis flap, and a great toe wrap-around flap. These triple flaps were transferred to resurface the defects of the mutilated hand, which was involved in the thumb, first web space, volar palm, thenar eminence, or radial aspect of wrist. The cumulative size of the defects ranged from 9 by 11 cm to 12 by 18 cm. Six patients with multiple defects of the hand and thumb underwent reconstruction using the described technique. The donor sites were covered by means of split-thickness skin grafting. All flaps survived, and the patients were satisfied with the functional and aesthetic outcome at 6 to 12 months’ follow-up. The average improvement of thumb opposition was 4.8 on the Kapandji scale. Sensory recovery of the thumb tip of S3 was achieved. There were no major donor site complications. The authors concluded that a chimeric flap based on the anterior tibial vessels is an excellent method of reconstruction of severe multilevel injuries of the hand, including thumb loss.
ANATOMIC LANDMARKS

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>The flap comprises the skin of the instep between the first metatarsal head distally to the midpoint of the heel proximally. It involves entirely non-weight-bearing skin.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
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<tr>
<td>Composition</td>
<td>Fasciocutaneous.</td>
</tr>
<tr>
<td>Flap Type</td>
<td>Type B.</td>
</tr>
<tr>
<td>Dominant Pedicle</td>
<td>Medial plantar artery.</td>
</tr>
<tr>
<td>Minor Pedicle</td>
<td>Myocutaneous perforating vessels from the abductor hallucis brevis and flexor digitorum brevis.</td>
</tr>
<tr>
<td>Nerve Supply</td>
<td>Medial plantar nerve, L4-L5.</td>
</tr>
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Section 14E

FOOT

Medial Plantar Artery Flap

CLINICAL APPLICATIONS

Regional Use
- Plantar foot
- Ankle

Distant Use
- Microvascular transplantation for the contralateral foot
ANATOMY OF THE MEDIAL PLANTAR ARTERY FLAP

Fig. 14E-1

**Dominant pedicle:** Medial plantar artery
ANATOMY

**Landmarks**  The flap comprises the skin of the instep between the first metacarpal head distally to the midpoint of the heel proximally. It involves entirely non-weight-bearing skin.

**Composition**  Fasciocutaneous.

**Size**  $12 \times 6$ cm.

**Arterial Anatomy (Type B)**

**Dominant Pedicle**  *Medial plantar artery*

**Regional Source**  Posterior tibial vessels.

**Length**  12 cm.

**Diameter**  1.5 mm.

**Location**  The medial plantar artery enters the foot between abductor hallucis and flexor digitorum brevis.

**Minor Pedicle**  *Myocutaneous perforating vessels from the abductor hallucis brevis and flexor digitorum brevis*

**Regional Source**  Medial plantar artery.

**Length**  2 cm.

**Diameter**  0.4 mm.

**Location**  Superficial surface of the muscles.

**Venous Anatomy**

Venae comitantes accompany the medial plantar and tibial vessels.

**Nerve Supply**

**Sensory**  The medial plantar nerve, L4-L5, is one of the terminal branches of the tibial nerve, entering the foot with the medial plantar vessels.
Vascular Anatomy of the Medial Plantar Artery Flap

Fig. 14E-2

Dominant pedicle: Medial plantar artery (D) arrows, Fasciocutaneous branches of medial plantar artery
Fig. 14E-2

**Dominant pedicle:** Medial plantar artery (D)

*pt*, Posterior tibial artery; *t*, lateral plantar artery
**FLAP HARVEST**

**Design and Markings**
The flap is designed on the non-weight-bearing instep skin. The distal limit of dissection is the head of the first metatarsal; the proximal limit is the cubicle of the navicular bone.

![Diagram showing the flap harvest area on the foot.](image)

**Fig. 14E-3**

**Patient Positioning**
The patient is placed in the prone or lateral decubitus position with the instep fully exposed.
GUIDE TO FLAP DISSECTION

Standard Flap
The skin island is incised around its periphery, and dissection is taken down through the plantar fascia, exposing the flexor digitorum brevis laterally and abductor hallucis medially. Distally and just proximal to the metatarsophalangeal joint, the two muscles are separated to expose the medial plantar vessels and nerve. The vascular pedicle is divided, and the dissection is continued proximally toward the calcaneus beneath the vascular pedicle in the center of the flap. Dissection is deep to the plantar fascia at all times. The medial plantar nerve can be split from distal to proximal, which preserves sensation to both the flap the distal medial foot. This reduces donor site morbidity. Dissection of the pedicle is continued proximally to the tuberosity of the calcaneus.

FLAP VARIANTS

- Standard flap with incorporated abductor hallucis muscle
- Reverse V-Y advancement flap
- Microvascular island flap transfer
Standard Flap With Incorporated Abductor Hallucis Muscle
The standard flap is raised in the usual fashion, but on the medial side, the abductor hallucis muscle is incorporated using the techniques described in Section 14C.

Reverse V-Y Advancement Flap
The skin triangle is incised with its base distal. The flap is based on distal perforating myocutaneous branches through the abductor hallucis muscle. The skin island is mobilized in the traditional fashion, but connections between it and the muscle belly are preserved. The flap is then advanced and mobilized but will only move 1 to 2 cm with this technique.

Microvascular Island Flap Transfer
The standard skin island is raised, with extension of the dissection of the vascular pedicle right up to the bifurcation of the posterior tibial artery into its medial and lateral plantar branches.

ARC OF ROTATION

Standard Flap
The standard flap is elevated to the base of the heel and can be transposed to cover posterior heel defects adequately. Basing the flap on the medial plantar circulation and dividing the lateral plantar artery, the flap rotation can be extended slightly farther to incorporate ankle coverage.
Reverse V-Y Advancement Flap
The reverse flap slides forward along the long axis of the first metatarsal for 1 to 2 cm.

FLAP TRANSFER
For the standard rotation flap, the tissue is simply rotated into the defect, with care not to kink or twist the pedicle. For the V-Y advancement, traction sutures on the distal end of the flap allow the surgeon to determine which restraining fibers need to be cut to allow further advancement into the defect.

FLAP INSET
The flap is inset with strong cutaneous nonabsorbable sutures.

DONOR SITE CLOSURE
In a V-Y advancement, direct closure is usually feasible. When a transposition flap is used, the instep should be grafted with split skin.
CLINICAL APPLICATIONS

This 74-year-old woman presented with a melanoma of the heel. She required a wide excision of the heel and was reconstructed with a medial plantar artery flap. Because the foot had poor vascularity, with only one vessel run-off seen on an angiogram, the reconstruction was done in two stages with a flap delay.

Fig. 14E-7  

A, The heel defect after wide excision. B, The dotted line shows the border of the weight-bearing sole. The flap was designed within the non-weight-bearing portion of the foot. C, The flap was elevated in the subfascial plane, exposing the medial plantar nerve and the vascular bundle. D, The wound was closed over a silicone sheet and the recipient site was temporarily dressed. Note that the proximal portion of the flap was maintained. E, Ten days later, the flap was elevated and the skin incision completed. The flap was raised based on the medial plantar pedicle. F, After flap inset and skin grafting of the donor site. The flap was congested and turned white when closure was attempted, so the flap was only partially inset and closed with the patient under local anesthesia in the office 1 week later. G and H, Two weeks postoperatively, the flap is viable, has a nice contour, and the skin graft is healing. The patient began ambulating at 6 weeks postoperatively and required no further surgical interventions. (Case supplied by MRZ.)
This 51-year-old man underwent sentinel lymph node biopsy and wide local excision of an intermediate-thickness melanoma on the weight-bearing heel. Deep margins were confirmed to be free of disease. Physical examination revealed sensibility on the plantar foot, and Doppler examination confirmed the presence of both medial and lateral plantar vessels.

**Fig. 14E-8**  
A, The patient had an intermediate-thickness melanoma on the weight-bearing region of his left heel. B, A wide local excision left a defect of 6 by 4 cm over the heel. C, A 9 by 6 cm medial plantar artery flap was raised in a subfascial plane. Intraneural dissection was performed to isolate the cutaneous medial plantar nerve and preserve sensation to the flap. D and E, The flap was rotated to cover the defect. The donor defect was covered with a split-thickness skin graft. F, The postoperative course was uneventful, and the flap survived completely. The patient was bearing full weight on the sensate flap with usual footwear when seen 9 months postoperatively. (Case courtesy Geoffrey C. Gurtner, MD.)
This 54-year-old man underwent sentinel lymph node biopsy and wide local excision of an intermediate thickness melanoma on the weight-bearing heel. Deep margins were confirmed to be free of disease. Physical examination revealed sensibility on the plantar foot. Doppler examination confirmed the presence of both medial and lateral plantar vessels.

**Fig. 14E-9**  
A and B, The patient had an intermediate thickness melanoma on the weight-bearing heel of his left foot. C, A wide local excision left a defect of 12 by 6 cm over the heel and a portion of the weight-bearing lateral sole. D, A 10 by 5 cm island medial plantar artery flap with a neurovascular pedicle was raised in a subfascial plane. Intraneural dissection was performed to isolate the cutaneous medial plantar nerve and preserve sensation to the flap.
Fig. 14E-9  E and F, The flap was rotated into the defect, and a split-thickness skin graft was used to cover the donor defect. G-I, The postoperative course was uneventful, and the flap survived completely. The patient was bearing full weight on the sensate flap with usual footwear when seen 8 months postoperatively. (Case courtesy Geoffrey C. Gurtner, MD.)
**Pearls and Pitfalls**

- The flap is designed on non-weight-bearing skin.
- For standard flap elevation, the split medial plantar nerve technique to preserve distal foot sensation should be employed.
- Preoperatively, the patency of the posterior tibial circulation should be assessed clinically, and if necessary, radiologically.
- The reverse medial plantar flap may not be reliable when the proximal medial plantar artery is divided, because the distal collateral circulation may be compromised.
- A history of recent deep venous thrombosis is a contraindication to performing this flap.

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**EXPERT COMMENTARY**

**Geoffrey C. Gurtner, Leila Jazayeri**

**Indications**

In 1954 Mir y Mir\(^1\) introduced the cross-leg medial plantar flap for resurfacing a heel defect. In 1979 Shanahan and Gingrass\(^2\) expanded the utility of this donor site with their description of a sensate pedicled fasciocutaneous flap based on the medial plantar artery. As more anatomic insight was gained, several additional modifications were introduced. Harrison and Morgan\(^3\) described an instep island flap in 1981 followed by Morrison et al's description\(^4\) of a free sensory instep flap in 1983. The concept of a perforator flap was then applied by Koshima et al\(^5\), leading to the successful transfer of free medial plantar perforator flaps for coverage of soft tissue defects in the fingers and foot. With the unveiling of several modifications, the medial plantar artery flap today can be used to reconstruct the ipsilateral heel, lateral plantar surface, lower tendo-Achilles area, medial ankle, contralateral plantar surface, and palmar finger and palm.

**Advantages and Limitations**

The surgical principle of replacing like with like highlights a unique advantage of the medial plantar artery flap in weight-bearing plantar reconstruction. The specialized fat pad and fibrous septa of the sole protect against trauma from continuous weight-bearing and shearing. The flap replaces the heel pad or lateral weight-bearing plantar surface with similar tissue that can withstand body weight and provide protective sensation without the need for nerve grafting. These unique features may help prevent pressure sores and may be advantageous compared with such options as the reverse sural flap and local extraplantar flaps.

Miyamoto et al\(^6\) investigated the donor site morbidity associated with the nerve transfer. They described 13 patients with transfer of instep island flap for heel reconstruction. Ten of the 13 were neurosensory flaps, all of which preserved light-touch cutaneous sensitivity and static two-point discrimination in the transferred tissue post reconstruction. Seven of the 13 patients, however, demonstrated sensory disturbances of the forefoot. One showed hypersensitivity and 5 showed hyposensitivity. These patients did not complain of these symptoms; they were discovered only by examination.
The highly vascularized nature of this flap is also an advantage. The dual axial and random blood supply allows transfer of a larger surface area when compared with flaps based solely on random blood supply. Another important advantage is the limited donor site morbidity. The inset is expendable non-weight-bearing skin, and the donor defect has sufficient circulation to readily accept a skin graft.

However, arterial compromise of the dorsalis pedis and peroneal artery is a contraindication to its use.

**Anatomic Considerations**

In general, the anatomy of this flap is straightforward. There are some considerations regarding the cutaneous branch of the medial plantar nerve, which is the larger of the two branches of the tibial nerve and arises beneath the abductor hallucis muscle, then runs adjacent to the medial plantar artery between the abductor and flexor digitorum brevis. The medial plantar nerve then usually divides into two branches. The medial of the two branches innervates the medial side of the great toe, and the lateral branch supplies the instep area.

**Personal Experience and Insights**

We use the medial plantar artery flap primarily for cancer reconstruction. Given the uncertainty of the zone of injury in lower extremity trauma, we chose not to use pedicled, perforator, or island flaps based in the medial plantar artery for reconstruction of traumatic plantar defects, although others describe its success in diabetic wounds. We hesitate to perform interfascicular dissection to raise a sensate flap in diabetic patients, because many of these patient’s have a significant component of peripheral neuropathy. Several studies have speculated that lack of a neurosensory flap transfer is linked to ulcer recurrence with this flap.6,8–10

We also choose to carry out the flap dissection in a subfascial plane. Others raise the flap superficial to the plantar fascia and base the flap on the proximal plantar subcutaneous plexus.10 A suprafascial dissection plane has also been described when raising a medial plantar artery perforator flap.5 In the subfascial dissection it is unnecessary to include the flexor digitorum brevis; however, we do raise surrounding fat with the neurovascular pedicle. For posterior defects the abductor hallucis may need to be divided to give additional length.

**Recommendations**

**Planning**

Preoperatively the patient can be assessed by physical examination for distal pulses and with handheld Doppler to confirm the presence of both medial and lateral plantar vessels. Sensibility to the rest of the foot can also be tested on preoperative examination.

The defect is measured precisely and marked on the instep of the foot with the long axis parallel to the medial plantar vessel. It may be difficult to get the vessels in the center of the flap. In fact, in our experience, the vessels lie on the medial aspect of the flap, and the lateral flap’s perfusion remains robust with this layout. The boundaries of the flap should not cross over to the weight-bearing surface of the lateral foot, and distally the flap is kept 1 to 2 cm behind the heads of the metatarsals.

**Technique**

We dissect the flap in a subfascial plane. Fibrous septa from the flap to deeper structures are divided as the dissection is carried out distal to proximal and lateral to medial. The vessels
are identified between the abductor hallucis and the flexor digitorum brevis muscle. The medial plantar nerve is identified adjacent to the medial plantar artery between the abductor and flexor digitorum brevis. In a sensate foot, an intraneural dissection is used to dissect out the cutaneous nerve from the main medial plantar nerve. The flap is then transposed into the defect and sutured in place over a drain. The resulting donor defect exposes the flexor digitorum brevis for application of a split-thickness skin graft.

**Postoperative Care**

Postoperatively the leg is immobilized for 5 days in a splint with a window for flap visualization. At 2 weeks postoperatively, the sutures are removed. A weight-bearing protocol is started at week 4. We start with 5 minutes of weight-bearing two to three times daily and advance to full weight-bearing in 1 week if no complications are encountered. Postoperatively most patients can use regular footwear. If additional support is needed, an 8 mm microcellular rubber insole can be worn postoperatively.

**Complications**

In their literature review on the medial plantar artery flap, Schwarz and Negrini reported an overall flap survival 142 of 145 flaps (98%); an additional 5 flaps (3%) developed partial necrosis. They discussed their own experience in 51 flaps in 48 patients. There was 1 flap necrosis, 3 infections, and delayed wound healing in 6 cases. Ulceration recurred in 7 feet in 14 months of follow-up. However, none of the patients in their series who had functional medial plantar nerves to begin with developed recurrent ulceration. This may support the speculation that the innervated flap transfer provides protective sensation that may prevent future ulceration. One of the patients with nerve transfer complained of decrease sensation in the forefoot for some months after surgery.

Miyamoto et al reported that 7 of 13 patients with medial plantar artery flaps with transfer of the cutaneous medial plantar nerve had hyposensitivity or hypersensitivity in the forefoot.

**References**

Bibliography With Key Annotations


Reconstruction of complex soft tissue defects in the hand remains a difficult challenge in reconstructive surgery. In this report, the authors introduced a combined medialis pedis and medial plantar fasciocutaneous flaps supplied by the lateral and medial branches of the medial plantar artery, which allows one-stage reconstruction of multiple soft tissue defects in the hand. Three combined medialis pedis and medial plantar fasciocutaneous flaps were transferred to repair soft tissue defects, including palmar and dorsal areas of hand, thumb pulp, and the dorsum of an index finger in three patients. All three flaps survived uneventfully, with coverage matching the texture and color of the recipient sites. The donor sites healed without complications. The experience from these cases proves that the combined medialis pedis and medial plantar fasciocutaneous flaps based on the medial plantar pedicle would be a valuable alternative for the reconstruction of complex soft tissue defects in the hand.


Treatment of composite tissue loss in the finger pulp is often difficult. The authors presented experience with using the medial plantar artery perforator flap for repair of finger pulp defects and restoration of fingertip sensation after traumatic injury. Free medial plantar artery perforator (MPAP) flaps were performed for digital pulp reconstruction in 10 patients (8 fingertip and 2 thumb tip injuries) between June 2006 and December 2007. The flap’s blood supply was the perforator vessel of the medial plantar artery, which was through the intermuscular septum between the abductor hallucis muscle and the flexor digitorum muscle. The recipient vessels were the digital artery and dorsal digital vein. The flap was not reinnervated during transfer procedures. The donor sites were closed primarily in all cases. Flap size ranged from 15 by 25 mm to 60 by 20 mm. All flaps survived. Partial loss occurred in one flap, due to venous congestion caused by excessive stitch tension. The donor sites healed uneventfully in eight cases, but mild wound dehiscence occurred in two cases. The follow-ups ranged from 6 to 29 months with the mean of 18.1 months. The mean of s2PD and m2PD were 8.8 mm and 6.8 mm at the patients’ last follow-up visits, respectively. MPAP flaps are good in terms of generally low morbidity, satisfactory cosmetic results, and durability. This flap is a valuable alternative method for repairing the glabrous finger pulp and tip defects.


It is well known that venous drainage of the medial plantar flap is performed by two venous systems: the cutaneous veins visible through the skin that drain into the great saphenous vein, and deep veins, namely, the accompanying veins of the medial plantar artery. However, there are only a few illustrations of the cutaneous veins of the sole in anatomic textbooks. Further clarification of the cutaneous veins of the sole was considered to be useful information in elevating the medial plantar flap. Whole-body or local injection with contrast medium was performed in 10 fresh cadavers. The skin and subcutaneous tissue were elevated and radiographed with a soft radiographic system. In an embalmed cadaver, macroscopic observation of the sole identified an intimate venous network formed by branches of the great saphenous vein, small saphenous vein, and dorsal venous arch. Vascular arrangement of the venous network was not random but was characteristic in each region of the sole. In the medial plantar region, vessels were arranged toward the anterior margin of the medial malleolus. In planning a medial plantar flap, taking the vascular arrangement into consideration will help to avoid venous congestion and extend the skin portion.

Free rather than local flaps are usually required for large plantar defects because of the lack of locally available tissue. The medial sural artery perforator free flap, recently introduced clinically by several authors, is a notable option for soft tissue coverage, but it has still not been widely used for reconstruction of various large plantar defects. Between 2005 and 2007, the authors used the medial sural artery perforator free flap to reconstruct soft tissue defects in plantar areas in 11 patients. Patient ages ranged from 10 to 68 years and follow-up ranged from 7 to 22 months. Flap sizes ranged from 10 to 14 cm long by 5 to 7 cm wide. Flaps survived in all patients. Marginal loss over the distal flap region was noted in one patient; this was treated successfully with a split-thickness skin graft. In another case, venous insufficiency developed, but salvage was successful with application of leeches. Long-term follow-up showed good flap durability with a protective sensation. The medial sural artery perforator flap provides sufficient durability for weight-bearing areas, even though it is a thin cutaneous flap. The authors considered this flap to be a reliable alternative for the reconstruction of large plantar defects.


The authors described three cases in which island medial plantar artery perforator flaps were successfully transferred for coverage of the plantar defects. This perforator flap is different from the medial plantar flap based on the medial plantar artery. The flap has no fascial component and is nourished only with the perforator of the medial plantar vessel. Therefore transection of the medial plantar artery is usually unnecessary. This flap can cover defects on the forefoot and heel without transection of the medial plantar system. The advantages of this flap are that there is no need for deep or long dissection for the medial plantar vessel, no exposure of the plantar sensory nerve, a short time for flap elevation, minimal donor site morbidity, relatively large flap survival, and no damage to the posterior tibial and medial plantar neurovascular systems.


Destruction of the thumb from a traumatic injury presents a much more significant influence on daily living than do injuries to the other digits. Various surgical techniques are used to repair distal defects of the fingers, especially thumbs. Seven patients (five men, two women) received free MPAP flaps to resurface the palmar defects of their thumbs. The flaps can be harvested with or without the main trunk of the medial plantar artery. The perforator of the MPAP flap was anastomosed to a proper digital artery, and the superficial vein of the flap was anastomosed to the dermal vein of the injured finger. These thumbs had no severe length discrepancy or metacarpophalangeal joint injuries. All patients underwent evaluations including static two-point discrimination, moving two-point discrimination, and Semmes-Weinstein testing 6 months after reconstructive surgery. All tests were carried out by the same occupational therapist. The mobility of the fingers was not restricted after surgery. Six flaps survived completely; one flap partially failed because of venous congestion. Sensory restoration was ideal for all MPAP flaps. The MPAP flap is a suitable choice for reconstructing palmar defects of the fingers, with less donor site morbidity. The cushiony character of the MPAP flap is anatomically similar to the pulp tissue of fingers, and sensory restoration is ideal compared with that of other reconstructive methods. Technical difficulty is focused on anastomosis of perforators with a diameter of 0.8 mm or less.


Defects of the distal third of the lower leg with exposed tendons or bone require either local or free flap coverage. Several flaps have been developed, and the distally pedicled peroneus brevis muscle flap has proved to be a valid local flap alternative. The peroneus brevis muscle is dissected from the lateral surface of the fibula from proximal to distal, but no farther than approximately 3 to 6 cm
proximally to the lateral malleolus, where the distalmost vascular pedicle from the peroneal artery enters the muscle consistently. This allows the muscle to be transposed to more distal lesions. The muscle is then covered with a meshed split-skin graft. Between 2002 and 2008, 10 patients with defects of the lower leg in the distal lower third were treated using this muscle flap. All flaps survived completely, and no secondary local flap was required. In our experience, no complication or patient discomfort was noted. Donor-site morbidity was acceptable and restricted to the scar in the lateral lower leg. As demonstrated by the two score evaluations, the functions of foot eversion and plantar flexion as well as ankle functionality and stability were maintained as a result of preservation of the peroneus longus muscle. This flap offers a convincing alternative for covering defects in the distal leg region. Its arc of rotation allows coverage of more anterior defects of the ankle, of defects of the Achilles tendon, and of the heel area as well as of lateral and medial malleolus areas. It is simple to raise and is often transposed easily within the wound without further dissection. As long as the peroneus longus is preserved, ankle instability is not expected.


The abductor hallucis muscle flap is commonly used as a proximally based flap in the management of ankle, heel, and midfoot lesions, where it is ideally suited for closing defects. This study investigated the anatomic details of this muscle in 13 fresh male cadavers. The medial plantar artery was studied by dissection and macroscopic analyses to document the relationship of its superficial and deep branches with respect to the abductor hallucis muscle. Three main patterns were described. Because preoperative radiologic studies of the plantar vessels correlate with the morphologic characteristics of the abductor hallucis muscle observed during surgery, such imaging may be useful in determining the appropriate flap design based on the patient’s unique pattern of medial plantar artery branching.


Providing sensation to the weight-bearing surface of the heel is vital in a sensate foot. Hence, resurfacing the weight-bearing surface of the heel requires stable skin cover and sensation. There are many options to fulfill the above requirements. Skin of the instep area can be raised as an island fasciocutaneous flap based on medial plantar vessels, with the branch of medial plantar nerve supplying the instep skin to provide the sensation. A medial plantar artery (instep) flap provides similar tissue with sensation and reaches the posteriormost part of the weight-bearing surface of the heel with ease. The author presented the relevant surgical anatomy, technique, and clinical experience with 12 patients.


Coverage of soft tissue defects of the heel has long been a challenge to reconstructive surgeons. The medial plantar artery flap has facilitated heel coverage since its development in the 1980s. The authors presented a prospective study from two centers assessing the complications and durability of this flap primarily in patients with sensory impairment. Fifty-one flaps were carried out in 48 patients. All patients but one had chronic plantar ulceration as a result of sensory loss; five patients had also developed squamous cell carcinoma. One flap underwent necrosis, and delayed healing was seen in four cases. Total flap survival was 98%. Minor revision of the flap or its pedicle was required in three cases. With a mean follow-up of 14 months, there were recurrences of ulceration in seven feet.


The authors treated 13 cases (15 fingers) of volar soft tissue defects with medial plantar venous flaps. There were 7 males (9 fingers) and 6 females (6 fingers); the patients’ average age was 30 years old. Their soft tissue defects were caused by electric saws in (4 cases, 5 fingers), crush injury (6 cases, 6 fingers), and burn scar removal (3 cases, 4 fingers). The size of soft tissue defects ranged from 1.0 by 0.9 cm to 5.8 by 3.3 cm. Surgeries were performed in 10 traumatic cases after 2 to 12 hours (4 hours average); elective surgical procedures were performed in the other 3 patients who had scars after burn injuries. The 15 medial plantar venous flaps were harvested to restore defects. The donor sites
were sutured directly or were covered with skin graft. All 15 venous flaps survived completely, and the donor and recipient sites healed by first intention. Eleven cases were followed for 2 to 12 months. The texture and color of the flaps were similar to those of adjacent normal skin, with a satisfactory appearance. Two-point discrimination was 6 to 9 mm. According to criteria for joint junction of total active range of motion and total active range of flexion, the results were excellent in 10 cases and good in 1 case. The medial plantar venous flap is easy to perform, has a rich blood supply and a high survival rate. It is an ideal and reliable choice for volar soft tissue defects of fingers.


The authors described a case of a 10-year-old boy who received a distally based, pedicled medial plantar artery flap to cover a defect on the distal lateral side of his right foot. The defect resulted from amniotic constriction. The flap served as defect coverage and was kept viable solely by the distal medial plantar vessels. Use of this particular kind of flap proves advantageous in that it provides good protection in the weight-bearing area of the foot while causing only a minor donor site defect.


Burn reconstruction of the forefoot remains a difficult challenge, because local flap alternatives are limited. The authors evaluated the efficiency of distally based medial plantar fasciocutaneous island flap for the coverage of forefoot defects resulting from release of toe contractures and burn debridement. Four patients with toe contractures and two patients with third-degree burns of the forefoot were treated. The flaps were elevated as with a fasciocutaneous base on the distal medial plantar artery. The skin over the pedicle was included as a part of the flap in three cases. The concomitant vein of the pedicle was anastomosed with the first plantar digital vein in four cases. The mean follow-up period was 10.4 months. In the early postoperative period, one flap that had been used to cover a third-degree burn caused by a high-voltage electrical injury was lost completely. The authors concluded that this flap is an appropriate alternative reconstructive option for the forefoot defect. Including skin and subcutaneous tissue over the pedicle to the flap protects the pedicle against kinking and compression. Venous supercharging of the flap improves venous drainage.


Plantar reconstruction is often challenging for plastic surgeons because of the peculiar anatomic features of this region. A large variety of reconstructive techniques for the plantar aspect of the foot have been described, including skin grafts, local flaps, fasciocutaneous flaps, perforator flaps, cross-limb flaps, and free flaps. The authors presented the case of a 64-year-old patient with insulin-dependent diabetes who sustained a large plantar tissue defect (9 by 4 cm) from a traffic accident; the wound extended to the base of the toes. After debridement of the wound, a subcutaneous flap was raised from the medial aspect of the lower leg in a subfascial plane. The flap was based on double vascularization from the greater saphenous vein and the perforator vessels from the posterior tibial artery, located anterior and inferior to the medial malleolus. The flap showed excellent vitality and long-term results with little donor site morbidity. The authors stated this flap represents a reliable surgical option in superficial plantar defects due to easy harvesting, short operative time, and minimal donor site morbidity. The subcutaneous flap of the distal medial fourth of the leg is a safe technique because of the vascular components of the pedicle. It provides durable coverage, mechanical resistance to pressure and shear stresses and, in selected cases (superficial defects, thin patients), is an interesting option when one wishes to avoid major free flap procedures.


An important principle that guides heel reconstruction is to provide sensate skin with a similar thickness to resurface the weight-bearing heel and avoid late flap ulceration. Among various techniques to achieve this result, the sensate medial plantar perforator flap is an excellent option; it provides durability to friction, a cushioning effect, and sensation. The authors performed an anatomic study
was performed to clarify the anatomy of the cutaneous perforators of the medial plantar artery and to
determine the optimal method of medial plantar artery perforator flap harvest. Fifteen cases of heel
reconstruction with the sensate medial plantar perforator flap were presented. The outcome of surgery
at a mean follow-up of 12 months was reported, and the indications for surgery, operative procedures,
advantages and disadvantages, and results are presented. Satisfactory results were obtained with a
good color and texture match for heel repair and a good sensory recovery. No functional deficit was
found at the donor site.

Yokoyama T, Tosa Y, Hashikawa M, et al. Medial plantar venous flap technique for volar
oblique amputation with no defects in the nail matrix and nail bed. J Plast Reconstr Aesthet

Skin grafting is a simple technique used for volar oblique amputation; however, it is not appropriate to
use this technique if the bone or tendon is exposed. Moreover, in volar oblique amputation, if the severed
section is large and elongated, skin grafting makes the lack of volume conspicuous, and reconstruction
with a V-Y advancement flap occasionally results in a nail deformity that resembles a parrot’s beak.
The authors used a medial plantar venous flap for the correction of large volar oblique amputation.
In volar oblique amputation, if the remaining nail matrix and nail bed are uninjured, patients can
expect the restoration of shape, function and sensory input after surgery. In this study, the authors
used the medial plantar venous flap for large volar oblique amputation cases and obtained good results.

Zgonis T, Roukis TS, Stapleton JJ, et al. Combined lateral column arthrodesis, medial plantar
artery flap, and circular external fixation for Charcot midfoot collapse with chronic plantar
ANATOMIC LANDMARKS

Landmarks: A direct perforator flap based on the lateral calcaneal artery termination of the perineal artery. The skin island lies beneath the lateral malleolus.

Size: 4 × 8 cm.

Composition: Fasciocutaneous.

Flap Type: Type A.

Dominant Pedicle: Lateral calcaneal artery.

Nerve Supply: Sural nerve S3.
Section 14F

FOOT

Lateral Calcaneal Flap

CLINICAL APPLICATIONS

Regional Use

- Posterior ankle
- Achilles tendon
ANATOMY OF THE LATERAL CALCANEAL FLAP

**Fig. 14F-1**

**Dominant pedicle:** Lateral calcaneal artery
ANATOMY

Landmarks  A direct perforator flap based on the lateral calcaneal artery termination of the peroneal artery. The skin island lies beneath the lateral malleolus.

Composition  Fasciocutaneous.

Size  4 $\times$ 8 cm.

Arterial Anatomy (Type A)

Dominant Pedicle  *Lateral calcaneal artery*

**Regional Source**  Peroneal artery.

**Length**  2 cm.

**Diameter**  0.9 to 1.8 mm.

**Location**  The lateral calcaneal artery is usually part of the termination of the peroneal artery lying behind and below the distal fibula. The peroneal artery lies immediately behind the shaft of the fibula, sending an osseous branch to the bone before passing behind the lateral malleolus. At this point the vessel is subcutaneous and lies 1 cm lateral to the Achilles tendon; it then passes over the extensor retinaculum covering the peroneus longus and brevis tendons. It has a curvilinear course over the calcaneus, and 1 to 2 cm proximal to the fifth metatarsal base it divides into dorsal and plantar branches. These communicate with the lateral tarsal artery.

Minor Pedicle  *Communicating branches from the lateral plantar artery; these vessels supply the basis of the reversed flap but are not reliable*

Venous Anatomy

Venous outflow is based primarily on the superficial venous plexus including the lesser saphenous circulation.

Nerve Supply

**Sensory**  The sural nerve runs 1 cm anterior and parallel to the lateral calcaneal artery and should be harvested with the flap so the vascular pedicle is not jeopardized.
VASCULAR ANATOMY OF THE LATERAL CALCANEAL FLAP

Flap design for typical Achilles wound

Distal incision is performed first, with identification and division of distal lateral calcaneal artery (arrow)

Lateral calcaneal artery is distal continuation of peroneal artery (arrow)

Further isolation of peroneal vessels, pictured here, is not necessary for rotation; flap is elevated on “cut as you go” basis, stopping once flap rotation and coverage are adequate

Fig. 14F-2

Dominant pedicle: Lateral calcaneal artery
FLAP HARVEST

Design and Markings
Preoperatively, the patient should undergo Doppler evaluation and an audible signal should be present, confirming the patency of this vessel. This is particularly important to ascertain in patients with vascular pathologies and in diabetics. Directional flow is worth evaluating, because patients may have prograde or retrograde flow that may compromise the surgical outcome. Arteriography can be valuable. Fortunately, the perineal artery is often the last vessel to occlude in many of these patients with vascular disease.

![Image of lateral calcaneal flap](Fig. 14F-3)

*Solid black curved lines* depict the design of the long version of the lateral calcaneal flap, here intended to reach a plantar heel wound. The distal end of the flap can be clamped for assessment of flap circulation before its division, in case a delay is indicated because of unsatisfactory perfusion.

The patient is marked with the leg dependent to fill the lesser saphenous circulation. The flap is marked as a proximally based rectangle with an average diameter of 4 cm.

Patient Positioning
The patient should be placed in the lateral decubitus or semiprone position.
GUIDE TO FLAP DISSECTION
The posterior incision just anterior to the Achilles tendon is incised first. This dissection can be taken down to the periosteum of the calcaneus. The tissues are dissected off the periosteum, leaving this latter stretch intact and thereby incorporating the vessels and nerves of the subcutaneous flap. The anterior incision is then made immediately posterior to the convexity to the lateral malleolus. The distal incision is then made to complete the outline of the flap. At this point the neurovascular structures will be found within the subcutaneous tissue, and these are divided. The flap is then mobilized from distal to proximal in the lateral plane beneath the deep fascia. The dissection is carried up to the level of the convexity of the lateral malleolus and is stopped at this point to prevent damage to the pedicle proximally.

![Image Description](https://example.com/image.png)

Typical Achilles defect reconstructed with lateral calcaneal flap

![Image Description](https://example.com/image.png)

Flap design, taking into account some loss of flap length with rotation

![Image Description](https://example.com/image.png)

Flap rotated and inset; donor site will require skin graft

Fig. 14F-4
FLAP VARIANTS

- Island flap
- Distally based flap
- V-Y advancement flap

Island Flap
The technique for the island flap is similar to that just described, differing only in that a proximal skin incision is made, allowing the pedicle to be protected within the adipofascial tissues posterior to the fibula. This permits slightly more mobility for inset. However, it still requires donor site skin grafting.

Distally Based Flap
A distally based flap is less reliable but can be used to reach plantar defects when other options are unavailable. The flap must be designed with the pivot point approximately 15 mm proximal to the base of the fifth metatarsal. The flap is elevated in the same plane but can be elevated with an arc of rotation reaching the lateral half of the dorsum or plantar surface of the foot. Vascularity is based on communications with the lateral plantar artery.

V-Y Advancement Flap
The V-Y advancement flap is raised with the pedicle protected in an adipofascial flap similar to that of the island flap. It relies on antegrade flow and is more reliable than the distally based flap.

ARC OF ROTATION
Given the nature of the tissue in this area, the arc of rotation is limited to the posterior heel and Achilles tendon at best. The distally based flap may reach the lateral dorsum or plantar aspects of the foot with a 90-degree rotation.

Arc of rotation of standard flap to Achilles tendon

Fig. 14F-5
FLAP TRANSFER
The tissue is transferred as a transposition or an advancement into the recipient bed.

FLAP INSET
Cutaneous nonabsorbable sutures are used to secure the flap to its recipient site.

DONOR SITE CLOSURE
Skin grafting is required to close the donor site in these patients.

CLINICAL APPLICATIONS
This case demonstrates the clinical use of the short version of the lateral calcaneal artery flap. This patient had a pressure sore with Achilles tendon exposure.

Fig. 14F-6  A, The patient is seen preoperatively. B, After debridement, a proximal pedicled flap was designed with its anterior border just posterior to the lateral malleolus. The distal flap border curved slightly forward and was longer than the defect to compensate for the loss of reach during the rotation. C, The dog-ear rotation is seen after flap inset, with the open donor site defect that required a skin graft. D, The flap provided satisfactory coverage, with spontaneous flattening of the dog-ear. (Case courtesy Louis C. Argenta, MD.)
This 64-year-old man with type 2 diabetes mellitus, chronic renal failure, and peripheral vascular disease presented with a 6-month history of a nonhealing Achilles tendon wound refractory to conservative treatment. A Doppler examination showed that he had a biphasic anterograde posterior tibial artery, a biphasic anterograde peroneal artery, and a biphasic retrograde dorsalis pedis. Given the patient's vascular supply and the location of the wound, he was considered a good candidate for a lateral calcaneal artery flap.

Fig. 14F-7  A, Flap design. B, The flap was elevated, including the lateral calcaneal vessels. C, A split-thickness skin graft was placed on the periosteum of the donor site, and a drain was placed. D, The healed flap and donor site are shown. (Case courtesy Christopher E. Attinger, MD.)
This 87-year-old man had type 2 diabetes mellitus, coronary artery disease, hypertension, and end-stage renal disease, and was receiving dialysis treatment. He presented with a 7-month history of a nonhealing distal Achilles tendon wound refractory to conservative treatment. The inciting event was unknown. A Doppler examination showed that he had a biphasic anterograde peroneal artery but monophasic flow of both the posterior tibial artery and dorsalis pedis artery. Given the patient’s limited functional status and comorbidities, the lateral calcaneal flap was an option, despite poor surrounding blood flow.

Fig. 14F-8  A and B, The wound is shown before and after debridement. C, The flap design is shown. D, The flap healed, but despite the skin graft, the donor site took 9 months to heal because of poor surrounding blood flow. (Case courtesy Christopher E. Attinger, MD.)
Pearls and Pitfalls

- Given the bulk of these flaps, dog-ears and contour deformities are significant issues. While they will settle with time, the skin grafted donor site tends to remain quite hollow, even when skin grafts have matured and contracted.

- Venous compromise is most common with the distally based flap but may occur with adipofascial proximally based variants as well.

- Great care should be taken when attempting to pass this flap beneath the cutaneous tunnel, although this is rarely feasible.

- Donor site delayed healing and contour deformity are significant issues with these donor sites. Hyperkeratosis is particularly common when skin grafts abut the plantar skin.

- Diminished sensation of the dorsal lateral foot is a routine problem with these flaps because of the harvest of the sural nerve within the flap. However, cross-innervation is usually adequate for protection of the foot.

EXPERT COMMENTARY
Benjamin J. Brown, Christopher E. Attinger

Indications
The indications for a lateral calcaneal artery flap are few but include posterior heel defects, distal Achilles tendon defects, and lateral malleolar defects. The flap is usually transferred as a transposition flap and therefore has limited mobility. We have principally used it for posterior heel and Achilles tendon defects and have preferred the supramalleolar flap to cover lateral malleolar defects.

Advantages and Limitations
One advantage of the lateral calcaneal flap is that it is adjacent local tissue, which provides an excellent match to the tissue surrounding the wound. It is easy to raise if the pedicle is included in the flap.

This flap has several limitations. Ulcers over the posterior heel usually result from poor flow along both the peroneal and posterior tibial artery. Therefore, to avoid flap loss and subsequently a larger tissue deficit, a very careful vascular examination must be performed before considering using this flap.

The lateral calcaneal flap is difficult to dissect only because the pedicle lies just above the calcaneal periosteum and it is easy to leave it behind. It must be carefully dissected free without damaging the pedicle or violating the underlying periosteum, which must be left intact to support a skin graft.

The pedicle of the flap is short and allows little reach. The tissue of the flap is generally not very pliable, making its inset difficult.

Finally, elevation of the lateral calcaneal flap will require transecting the sural nerve at the flap’s distal edge. Therefore a sensate patient will lose sensation over the lateral aspect of the heel and may develop a proximal neuroma unless the epineurium is sewn over the transected nerve.

Continued
Anatomic Considerations
The lateral calcaneal flap is elevated in a supraperiosteal plane and leaves a large deficit in an area susceptible to trauma. The periosteum can be skin grafted, but this donor site will always be susceptible to injury from what would normally be insignificant trauma. The donor site can be treated with negative-pressure wound therapy and/or a regenerative dermal matrix to build up the soft tissue before skin grafting to increase its long-term stability and durability.

Flap elevation will leave the patient’s lateral heel dependent on branches off of the anterior perforating branch of the peroneal artery superiorly, off branches of the lateral tarsal artery distally, and off branches of the medial calcaneal artery inferiorly. Ensuring adequate blood flow through those arteries on Doppler examination will help minimize donor site complications.

Personal Experience and Insights
The keys to using this flap are (1) to ensure good local blood flow from the surrounding arteries, (2) to stay in the supraperiosteal plane when dissecting the flap, and (3) to not expect too much reach, because its mobility is limited.

Recommendations
Planning
When planning the flap, it is important to perform a functional Doppler examination of the lower extremity to include the anterior perforating branch of the peroneal artery, the tarsal artery, the calcaneal branch of the posterior tibial artery, and, most important, the calcaneal branch of peroneal artery. It is also critical to determine whether the planned flap will actually cover the defect, because its mobility can be very limited. The flap is centered on the lateral calcaneal artery, visualized on Doppler ultrasonography.

Technique
The dissection begins distally by going down to periosteum and finding the lesser saphenous vein, the calcaneal artery, and the sural nerve. Dissection then proceeds proximally, always visualizing the pedicle above the dissection plane. We try to leave as much fat as possible on the underlying periosteum to reduce donor site morbidity. The proximal pedicle can be further mobilized to increase flap mobility. If the foot is sensate, the epineurium of the proximal sural nerve is closed over the transected axons.

The flap is rotated into the previously debrided and clean soft tissue defect. The donor site can then be directly skin grafted or covered with a dermal regenerative template, with or without negative-pressure wound therapy, and skin grafted later.

Postoperative Care
Postoperative care is critical for success. We have found that applying negative-pressure wound therapy on both the skin graft and mobilized flap helps ensure flap viability and skin graft take. The heel must be protected to prevent pressure on the flap and skin graft. Depending on patient compliance, protection is provided using the Ilizarov frame, a hollowed-out posterior splint, or an open cast to adequately off-load pressure from the flap.
Complications: Avoidance and Treatment

Because the donor site defect is considerable, the lateral calcaneal flap must be carefully planned so that it actually covers the defect. Blood flow must be adequate to both raise the flap and allow the donor site to heal as described previously. The flap must also be correctly elevated to avoid leaving the pedicle behind. The wound to be covered must be free of infection and treated with appropriate antibiotic coverage. Off-loading the flap for 3 to 6 weeks until the incisions and skin graft are healed is a key element to success.

Take-Away Messages

This flap has a very limited use for small distal Achilles tendon defects and posterior heel defects. Flap mobility is poor; therefore it can only be used as a transposition flap. It is crucial that the blood flow to both the flap and surrounding tissue is adequate. Flap dissection is difficult in that it is very easy to dissect too superficially and leave the pedicle behind (see Fig. 14F-9). Off-loading in the postoperative period is the key to a good outcome.

References


Fig. 14F-9  A, This lateral calcaneal flap died when it was dissected, leaving the underlying pedicle behind. B, The flap was debrided, and the wound was treated with negative pressure until it could be skin grafted.
Bibliography With Key Annotations


This is a review of island modifications of the lateral calcaneal artery flap, including use as an island flap, V-Y advancement flap, or bilobed-shaped island advancement flap. As a local flap, this is appropriate only for small and medium-sized defects of exposed calcaneus bone or tendon. The island flap is equivalent to the long version of the classic lateral calcaneal artery skin flap and has a greater arc of rotation that can even reach the medial malleolus. The V-Y advancement flap eliminates the need for a skin graft of the donor site and its concomitant contour deformity. Tunnelling of the flap under normal skin, as required with an island flap with the potential for compression of the pedicle, is also avoided by the latter design.


The lateral calcaneal artery flap is a simple, stable, sensate flap. The island flap version results in a better aesthetic result at both the donor and recipient sites. It is limited for coverage of heel defects smaller than 6 cm in diameter.


The lateral calcaneal artery island flap is a simple, stable, sensate, and safe and versatile flap for defects around the ankle and heel. The author performed this flap in 11 patients, and has used this flap to cover defects around the medial malleolus without any delay (extended lateral calcaneal artery island flap). Results were reported.


This is the classic paper on the anatomy and clinical usefulness of the lateral calcaneal artery flap. As a proximal pedicled skin flap, a vertical or short version was found valuable to cover the Achilles tendon, and a long version curving around the dorsolateral foot could reach the plantar surface of the heel.


The key factor in ensuring the reliability of any skin-bearing flap is the vascular supply to the fascial plexus. The numerous origins of the deep fascial perforators to this plexus have prompted an array of terminology intended to encompass all possible flap options. The author reviewed the history of the evolution of cutaneous flaps to provide insight essential in understanding a simple proposal for their classification. All fascial perforators course either directly from a source vessel or indirectly first through some other tissue to ultimately reach the suprafascial layer; therefore the corresponding flaps based on any such perforators could most simply be called either direct perforator flaps or indirect perforator flaps, respectively.


A V-Y advancement lateral calcaneal artery flap from the dorsolateral foot was devised to prevent the contour deformity at the donor site that could now be closed directly. It has a proximal pedicle much like an adipofascial flap, as does the island flap version. This design eliminates the disadvantages of the lateral calcaneal artery flap, and retains all the advantages of both the antegrade pedicled and island flap varieties.

Reverse flow into the lateral calcaneal artery is possible via distal connections with the lateral tarsal artery and a branch of the lateral plantar artery. This allows use of a distally based lateral calcaneal artery flap.

The arterial pedicle of the lateral calcaneal artery flap has a caliber greater than 1 mm at the level of the proximal calcaneus, and the lesser saphenous vein is even larger. These are more than sufficient dimensions to permit its use as a free flap wherever a thin, potentially sensate flap is required.

The authors reported their results using the lateral calcaneal flap in three patients. The flap was approximately 3 cm wide in all cases. In two patients, the donor site was skin grafted. In the third patient, the flap was transposed transversely. One patient had paresthesia 8 months postoperatively, at the lateral part of the dorsum of the foot.
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Credits

Fig. 8A-10, A-N  From Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, Kentucky.

Fig. 8C-2  From Mei J, Tang M, Morris SF. Vascular basis of dorsal forearm perforator flaps. [Submitted to Plastic and Reconstructive Surgery, 2011.]

Fig. 9C-4, A-E  Adapted from Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, Kentucky.

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Fig. 9E-13, A-D  From Christine M. Kleinert Institute for Hand and Microsurgery, Inc., Louisville, Kentucky.

Fig. 13B-8, A-C  From Pu LL. Soft-tissue coverage of an open tibial wound in the junction of the middle and distal thirds of the leg with the medial hemisoleus muscle flap. Ann Plast Surg 56:642, 2006.

Fig. 13B-9, A-C  From Pu LL. Further experience with the medial hemisoleus muscle flap for soft-tissue coverage of a tibial wound in the distal third of the leg. Plast Reconstr Surg 121:2027, 2008.

Fig. 13B-11, A and B  Adapted from Pu LL. Further experience with the medial hemisoleus muscle flap for soft-tissue coverage of a tibial wound in the distal third of the leg. Plast Reconstr Surg 121:2026, 2008.

Fig. 13B-12  From Pu LL. Soft-tissue coverage of an open tibial wound in the junction of the middle and distal thirds of the leg with the medial hemisoleus muscle flap. Ann Plast Surg 56:641, 2006.

Fig. 13B-13  From Pu LL. The reversed medial hemisoleus muscle flap and its role in reconstruction of an open tibial wound in the lower third of the leg. Ann Plast Surg 56:61, 2006.
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