Free Flaps in Head and Neck Reconstruction

A Step-By-Step Color Atlas

Raul Pellini
Gabriele Molteni
Editors

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Editors
Raul Pellini
Department of Otolaryngology-Head and Neck Surgery
IRCCS "Regina Elena" National Cancer Institute
Rome
Italy

Gabriele Molteni
Department of Otorhinolaryngology-Head and Neck Surgery
University Hospital of Verona
Borgo Trento
Verona
Italy

Department of Surgery, Dentistry
Paediatrics and Gynaecology
University of Verona
Verona
Italy

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To Pasquale, dear friend and colleague

Foreword

Development of reconstructive surgery focusing on free flaps in head and neck oncology led to incredible improvements in terms of indications as well as oncological and mostly functional results in the last decades.

The present Atlas is the final expression and synthesis of three important surgical schools with many years of experience in this field. This book is proposed as a step-by-step manual that, based on many years of shared surgical experience, displays to the scientific community the best know-how of the involved teams.

The editors, even if still relatively young, play a primary role in the scientific community thanks to their commitment, passion, international experiences in the field of reconstructive surgery. They represent a brilliant example not only for their high professionalism but also for the way they always deal with this complex theme, with correct therapeutic choices, multidisciplinary approach, and teaching young doctors to improve.

I am sure this book will soon become a cornerstone for every surgeon who wants to approach a complex argument as the head and neck reconstructive surgery.

Livio Presutti

Foreword

It is with great pleasure that I write this foreword to the compendium of surgical anatomy of the revascularized free flaps, written by Dr. Gabriele Molteni and Dr. Raul Pellini. For many years, I have been collecting and writing books on anatomy and surgical techniques, combining my passion for head-neck surgery, my academic commitment as Director of the Graduate School in Maxillo-Facial Surgery at the University of Verona. I have known Gabriele personally for many years and I appreciate his surgical talent, his precision in work, and his humanity towards the patient. After training at the school of Otorhinolaryngology of Modena directed by Prof. Livio Presutti, he joined my reconstructive team enriching it with his own presence. Considering Dr. Molteni and Pellini's skills and great passion for their work, I believe that this compendium has all the characteristics to be an important element in the formation of a new generation of microsurgeons. The images and the high quality of the intraoperative photographs will be a valid help for all the students, the doctors in training, and the specialists who wish to deepen their knowledge in this subject. The knowledge of anatomy, precise and careful dissection, preservation of structures and their functions are dogmas that must accompany every doctor who looks at reconstructive microsurgery, and this book contains each of these concepts. The excellent illustrations allow a clear and precise understanding of the complex topographical relationships between muscles, vessels, and nerves and guide the surgeon step by step in the dissection of the most important revascularized flaps, useful for the reconstruction of the head-neck area. This book should be a valuable resource in the library of every trainee and can be a good guide for all fellow surgeons who practice this discipline.

Pier Francesco Nocini

Foreword

Nowadays, surgical removal of head and neck cancer very often requires reconstruction. In the last 40 years, the limits of surgical ablation have been progressively extended by the initial introduction of pedicled flap followed by microvascular free tissue transfer. This new method has allowed an improved reconstruction and cosmesis as well as functionality.
Many different free flap solutions have been proposed, all of them based on the concept that any artery supplies the vitality of a specific territory and its homologous transplantation to a different site allows it to transfer human tissue from a site where its loss is less significant to another site where tissues are needed.

Raul Pellini has worked close to me for 20 years, and progressively he has increased his qualification and skill in HN microvascular free tissue transfer, becoming one of the international leaders in this branch. Gabriele Molteni has also dedicated many years to this field.

It is important and has to be their mission to transfer this knowledge to young doctors who are entering this field.

Many simple and composite flaps have been described considering the donor site morbidity, the shape of the defect, the different type of tissue removed and that have to be replaced as well as the patient's general and local condition.

Mandatory steps in this surgery are the knowledge of the anatomy of the donor site, especially focused on vascular supply, flap harvesting, vascular implant with its peculiarity, insert and integration of transferred tissue, and advanced monitoring and late follow-up.

In this book, young surgeons who fell in love with this type of surgery can find all the aspects of these techniques helpful in order to have the necessary guide to practice and improve these methods.

Moreover, several internationally renowned experts have been included in the completion of this book.

It has been a great pleasure and honor for me to have the opportunity to write a foreword to this book, and I am sure that all the efforts of Raul and Gabriele will be recognized through the advantages of lecturers.

Giuseppe Spriano

Preface

The mind is like a parachute. It only functions when it is open

In surgery, open mind means finding new ways to do old things. Microvascular techniques are nowadays a well-established method, and free flap reconstruction in head and neck surgery spread all over the world in the last decades.

In the era of new technologies and improvement of radiation therapy and new target therapies, the role of surgeons remains pivotal in the treatment of head and neck cancer. Nowadays, H&N surgeons are dealing more and more with previously irradiated patients and second or third primary tumor. In this scenario, free flaps remain the cornerstone of reconstruction due to their versatility and optimal vascular perfusion in a fibrotic contest.

Reconstructive surgeons are growing in number, and many books have been written on this topic. Dissection courses are mandatory before approaching this difficult surgery that require knowledge of 360° anatomy and also of microvascular techniques.

A practical and comprehensive step-by-step atlas with very detailed pictures from human bodies that can teach how to harvest a flap for head and neck reconstruction is not easy to find. Often, some surgical steps are lacking, and young surgeons at dissection course need more sources to proceed with flap harvesting. It is for these reasons that we start thinking about writing an atlas with the most detailed pictures of all surgical steps in harvesting free flaps for head and neck reconstruction: a book that should be comprehensive, clear, and easy-to-use for everyone independently from his level of experience in this field.

Raul Pellini
Department of Otolaryngology Head Neck Surgery
IRCCS Istituti Fisioterapici Ospitalieri
Rome, Italy

Gabriele Molteni
Department of Otorhinolaryngology-Head and Neck Surgery
University Hospital of Verona Borgo Trento
Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology,
University of Verona
Verona, Italy

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To Daniele Liguori for the wonderful drawings

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Part I

General Aspects

1 Free Flaps in Head and Neck Reconstruction

M. Ghirelli, G. Molinari, F. Mattioli, R. Pellini, and G. Molteni

1.1 Introduction

In the last decades, the treatment of head and neck tumors has shown important innovations regarding surgical and nonsurgical treatments, but above all, quality of life of the cancer patient and impact of treatments on functional and esthetic outcomes have been placed at the center of attention. In selected cases, new radiotherapy systems (such as IMRT or proton therapy) and chemotherapeutic regimens have overtaken the surgical treatment, which may be burden by high morbidity. On the other hand, either in a primary setting or as a salvage treatment, reconstructive surgical techniques have developed with the aim of restoring anatomical integrity, function, and esthetics.

These are the main reasons why, although overall survival of head and neck cancer patients has mildly increased over the past decades, morbidity from locoregional treatments has significantly reduced.

The use of free tissue transfers and microvascular anastomosis for the reconstruction of head and neck defects from extirpative oncologic surgery is a relatively recent practice. Before the past three decades, the majority of head and neck wide defects were closed with either local tissue or random skin flaps.

1.2 The Ancient Times

The very beginning of reconstructive surgery could be placed in India around 1500 BC: a local pedicled forehead flap was first described for the reconstruction of Lady Surpanakha's nose, which had been amputated from Prince Lakshmana, as a punishment. Some centuries later, the Sushruta Samhita (in Sanskrit "the text on surgery attributed to Sushruta") reshows the reconstruction of the nose with the same flap [1].

The use of head and neck reconstruction techniques reappears in the fifteenth century in Italy where Gaspare Tagliacozzi (1545–1599), an Italian surgeon and a renowned pioneer of plastic and reconstructive surgery, improved the procedures previously described by Gustavo and Antonio Branca.

M. Ghirelli (✉) · G. Molinari · F. Mattioli
Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital of Modena, Modena, Italy

R. Pellini
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

G. Molteni
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

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Fig. 1.1 One of the first examples of reconstruction technique described by Tagliacozzi

Fig. 1.2 Gaspare Tagliacozzi

In his groundbreaking book entitled *De Curtorum Chirurgico Per Insitionem* (*On the Surgery of Mutilation by Grafting*), he described the surgical procedures in great detail (Fig. 1.1 and 1.2).

He focused his work on a so-called cutaneous flap, harvested from the arm. However, it is not clear when the "cutaneous flap" was first applied with the modern technique.

1.3 Pedicled Flaps

For a long time, head neck defects have been repaired with local rotation flaps or with free skin grafts, not considering rehabilitation or esthetic result important.

The first step in the development of reconstructive technique could be recognized in the use of pedicled flaps (fasciocutaneous or fascio-myocutaneous).

The first report about a pedicled flap was described by Tansini in 1886: he used a pedicled latissimus dorsi flap for a thoracic reconstruction. Time has to pass by to see the first application of the same latissimus dorsi flap for reconstruction in the head and neck area, as described by Quillen in 1978 [2].

Another pedicled flap, among the first that have appeared in the history of reconstructive head and neck techniques, is the temporalis muscle flap. Described by Golovire in 1898 [3], it was subsequently taken up by several authors in the 1970s with various applications, from facial paralysis rehabilitation to reconstruction of skull base defects.

In 1963, McGregor [4] first introduced a forehead flap for reconstruction of oral defects and in 1965, Bakamjian first described the deltopectoral flap [5]. These last two flaps had been the gold standard for most head and neck reconstructions in the 1960s and 1970s, before the introduction of myocutaneous flaps, which carried the great advantage of the immediate reconstruction since autonomization of the flap was not needed. This technical achievement avoided long hospitalization and multiple surgeries on the same patient.

Conley was the first to report use of the trapezius pedicled flap incorporating the muscle and bone in 1972 [6]. Ariyan (1979) [7] and McCraw and Dibbell (1976) [8] popularized the flap design that we now refer to as the superior trapezius flap, which is an extension of Conley's original work.

Design and successful application of other pedicled cutaneous and myocutaneous flaps arose, such as the pectoralis flap. The discovery that each vessel nourishing the skin comes from arteries within the muscle led to the intuition that the transfer of the muscle and its vascular pedicle could include the overlying skin, creating a myocutaneous flap. The first uses are reported in 1947 when Pickerel [9] et al. used the pectoralis myocutaneous flap for the reconstruction of thoracic defects. Subsequently, in 1979, Ariyan recognized the tremendous potential of the musculocutaneous unit based on the pectoralis major for the reconstruction of a high number of wide head and neck defects. The pectoralis myocutaneous flap was considered the "workhorse" flap of head and neck reconstruction during the 1970s.

Pedicled flaps shortly became the first-choice reconstructive flaps being easy and quick to harvest, as they do not require a multi-team for the preparation or dedicated instrumentation. Moreover, they provide a good volume of reconstruction with overall low morbidity.

1.4 From Pedicled to Free Flaps

On the other hand, some limits of the pedicled flaps, such as the limited length of the vascular pedicle and the need of a pliable and thin flap in some cases, contributed to the search of new reconstructive strategies.

From the late 1960s to the early 1980s, the need for a more "tailored" surgery, the study of new body segments that can be used for the transfer of even composite flaps, as well as the increasing confidence with vascular mapping in different anatomic sites (especially thanks to Nahai and Mathes during the 1970s), were the major factors that led to a new era in reconstructive surgery: the introduction of free flaps.

1.5 Microsurgery

The spread of free flaps is necessarily intertwined with the development of the modern microsurgery. This surgical branch, which embraces more specialties, has its roots on three fundamental pillars.

We find the first, and perhaps the most important one, in 1902 when Alexis Carrel reported the triangulation method of the end-to-end anastomosis that is still routinely used today and for which he was later awarded the Nobel Prize in 1912 (Fig. 1.3) [10].

The second pillar is the introduction of anticoagulation. Heparin was discovered in 1916 by Jay McLean [11], a medical student at Johns Hopkins University, together with Howell and Holt. The ability to control blood clotting was an essential step forward in the development of microvascular surgery.

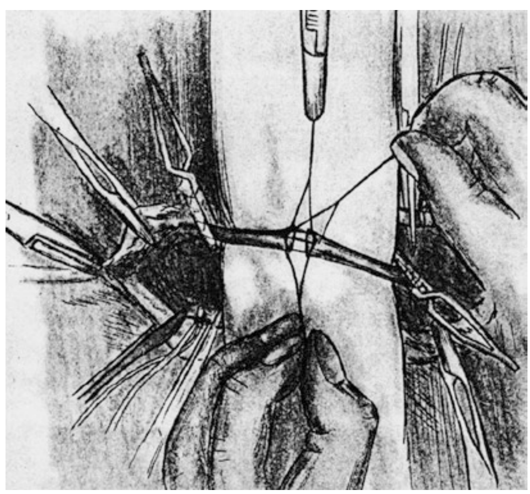

Fig. 1.3 "The triangulation technique" by Carrel

The third one concerns the introduction of visual magnification systems in the medical field. In 1876, Saemich first used binocular glasses with magnifying power in clinical practice.

The first surgeon to operate with the aid of a microscope was the Norwegian otolaryngologist Carl-Olof Siggram Nylén (1892–1978) who adapted a monocular Leitz-Brinell microscope (designed to be used for hardness testing and having a low magnification and long working distance) for inner ear surgery in 1921. In 1922, Gunnar Holmgren was among the first otolaryngologists who immediately recognized the benefits of the microscope, and he developed new surgical techniques, including stapedectomy and resection of acoustic neuromas.

In 1952, Dr. Hans Littmann (1908–1991), head of Med-Lab at Zeiss Opton Oberkochen, West Germany (now Carl Zeiss AG), and his team of technicians designed their first operating microscope. They started a new era by inventing a microscope capable of changing magnification without changing the focal length. His design, the Zeiss-Opton, provided 200 mm of working distance and magnifications of 4, 6, 10, 16, 25, 40, or 63 selectable through a rotary Galilean system.

In 1953, exploiting the intuition of Horst L. Wullstein, an otolaryngologist from Gottingen, who designed a moving arm on which mount the microscope to improve its mechanical flexibility, Littmann manufactured the "Zeiss OPMI 1" (Zeiss Operating Microscope 1), the first "modern" microscope, as the ones in use nowadays.

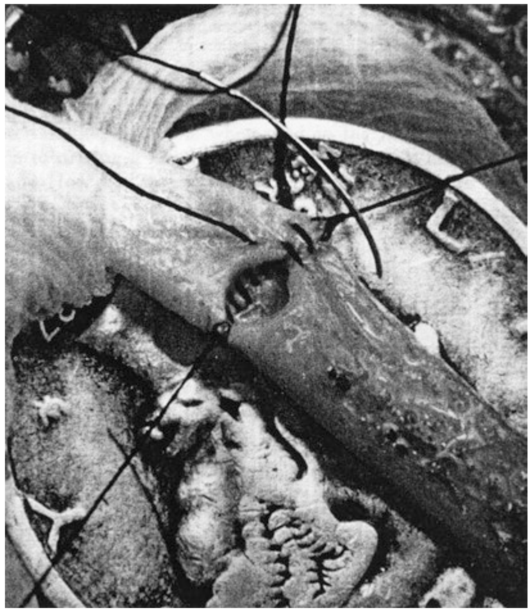

Fig. 1.4 The first vascular anastomosis performed with microscope

Fig. 1.5 Microsurgical instrumentations designed by Jacobson

1.6 Applied Microsurgery

During the 1960s, we find the pioneers of microsurgery and their first attempts to apply it to clinical practice. The use of the microscope to perform the first microvascular anastomoses is attributed to Jules Jacobson, a Vermont vascular surgeon, who performed an anastomosis on less than 1.4 mm vessels in 1960. The term microsurgery was born (Fig. 1.4). In 1963, Jacobson designed the microsurgical instrumentation that is being used still today, even if modified in some details (Fig. 1.5).

Buncke [12] gains the reputation of founding father of microsurgery as he first performed numerous experiments involving replanting or transplanting tissues in laboratory animals.

The first attempts in applied microsurgery are related not to head and neck reconstructive surgery but to limbs reimplantation trying to reduce the percentage of post-traumatic amputation.

One of the first historically reported attempts came in 1958, when Tamai and Onji tried to reimplant an incompletely amputated thigh on a 12-year-old girl at Nara Medical University Hospital, but the limb was lost after four weeks due to infectious thrombotic problems [13].

The first successful limb reimplantation was performed in 1962 by Malt and McKhann who reimplanted an amputated arm in a 12-year-old boy in Boston (the paper was published in 1964) [14].

The first publications concerning the use of free revascularized flaps for reconstruction of distant sites are sporadic: in 1959 by Seidenberg [15] who reconstructs a cervical esophagus with a flap of jejunum, while in 1965 the first reported experimental free skin flap transplantation of abdominal skin flap based on the superficial epigastric vascular pedicle was performed in a dog by Krizek and associates.

In 1965, Tamai reworked the vascular clamps used for the microsurgical treatment of intracranial aneurysms, transforming them into the vascular clamps used today for microsurgical vascular anastomoses [13].

During the 1960s, we find such a constant increase in microsurgical procedures that in 1967 the world's first panel on microsurgery was held at the Annual Meeting of the American Society of Plastic and Reconstructive Surgeons in New York City.

However, the most substantial development of microsurgery applied to reconstructive techniques began in the following decade, with the use of composite free flaps. In 1971, Strauch et al. [16] first reported a pedicled vascularized rib transfer to the mandible in dogs, demonstrating the possibility of a vascularized bone transfer.

McLean and Buncke used omentum pedicled on the gastroepiploic vessels to cover a cranial defect in 1972 [17]. In 1973, Daniel and Taylor [18] described the first cutaneous free flap, and in the same year, Ueba and Fujikawa described a case of congenital ulnar pseudarthrosis treated with a fibula free flap. They published this report after nine years of follow-up in 1983 [19].

In 1976, Baker and Panje were the first to publish the use of cutaneous free flaps for the reconstruction of head and neck defects. In the same year, Harii described gracilis muscle flap as one of the first musculocutaneous flaps to be transferred by microvascular technique and popularized it for dynamic facial reanimation [20].

In 1979, Watson et al. [21] reported the first successful microvascular transfer of a free latissimus flap; in the same year, Taylor and colleagues described iliac crest composite flap based on the deep circumflex iliac artery (DCIA).

In 1978, a fasciocutaneous free flap from the volar aspect of the forearm and pedicled on the radial artery was first used in China. When this so-called Chinese flap was originally described by.

Yang et al. in 1981 [22] and Song et al. in 1982 [23], both groups already had performed more than 100 successful flap transfers.

In 1980, dos Santos [24] published the dissection study on the cadaver of the scapula limb and the connected circle. In 1982, Gilbert and Teot [25] published the first clinical transfer of a free scapular flap. The studies on the subscapular circle conducted by Toet will lead to the use of osteocutaneous composite flaps as a variant of the scapular flap popularized in 1986 by Swartz [26]. While in 1982, Nassif and coworkers proposed to use the descending septocutaneous branch of the circumflex scapular artery as the nourishing skin vessel defined as parascapular skin flap [27].

In 1983, Chen and Yan were the first to report about an osteocutaneous fibula flap [28]. This extension of flap raising became possible following the proposal of Gilbert to use a lateral approach for harvesting the bone flap in 1979, which was easier to perform and allowed for visualization of the cutaneous branches of the peroneal artery. This approach is the most used today [29].

In 1980, Pennington and Pelly [30] first reported a free rectus abdominis musculocutaneous flap based on the deep inferior epigastric artery and vein.

One of the most recent revolutionary concepts in the free flap era was introduced in the 1980s, and it is design of free flaps based on cutaneous perforators. This technique is based on the fact that it is not always necessary to include the underlying muscle in the flap, but it is technically possible to isolate the perforating vessel, excluding the unnecessary tissues.

The anterolateral thigh (ALT) free flap was first described by Song et al. in 1984 [31] as a soft tissue flap that is perfused by septocutaneous branches of the lateral circumflex femoral artery. The ALT flap was popularized for the head and neck reconstruction in the 1990s by Koshima et al. [32] and Kimata et al. [33]

Koshima and Soeda in 1989 [34] introduced the deep inferior epigastric perforator flap. In 1998 again, Koshima introduces the concept of "supermicrosurgery" which will later pave the way to the free-style flaps described by Wei in 2004. Wei should also be mentioned as the first to approach the vascular pedicle of the flap in a retrograde way, from the perforating vessel toward the main one [35].

The history of reconstructive surgery, as described in this chapter, was born in ancient times and has arrived at our recent past. The variety of reconstructive options available nowadays promises to meet almost any reconstructive need in such an anatomically and functionally complicated area as the head and neck. However, in an attempt to obtain the best functional and esthetic outcome for each specific patient, reconstructive surgery in the head and neck district is a developing field of research. Taking advantage of the brilliant ideas of the surgeons in their everyday practice history of reconstructive surgery is fortunately still in progress.

References

1. Sushruta S. The Sushruta Samhita. English translation based on original Sanskrit text. Kaviraj Kunja Lal Bhishagratna, ed Bose. Calcutta: Kaviraj Kunja Lal Bhishagratna; 1916. p. 1907–16.
2. Quillen C, Shearin J, Georgiade N. Use of the latissimus dorsi myocutaneous island flap fur reconstruction in the head and neck area. Plast Reconstr Surg. 1978;62:113.
3. Golovine SS. Procede de cloture plastique de l'orbitc apres l'exenteration. J Fr Ophtalmol. 1898;18:679.
4. McGregor I. The temporal flap in intraoral cancer: its use in repairing the post-excisional defects. Br J Plast Surg. 1963;16:318.
5. Bakamjian VY. A two-stage method for pharyngoesophageal reconstruction with a primary pectoral skin flap. Plast Reconstr Surg. 1965;36:173.
6. Conley J. Use of composite flaps containing bone for major repairs in the head and neck. Plan Reconstr Surg. 1972;49:522.
7. Ariyan S. One-stage repair of a cervical esophagostomy with two myocutaneous flaps from the neck and shoulder. Plast Reconstr Surg. 1979;63:426.
8. McCraw JB, Dibbell DG. Experimental definition of independent myocutaneous vascular territories. Plast Reconstr. 1977;60:212.
9. Pickerel KL, Baker HM, Collins JP. Reconstructive surgery of the chest wall. Surg Gynecol Obstet. 1947;84:465.
10. Carrel A. La technique operatoire des anastomoses vasculaires et la transplantation des visceres. Lyon Med. 1902;98:859–63.
11. McLean J. The thromboplastic action of cephalin. Am J Phys. 1916;41:250–7.
12. Buncke HJ Jr, Schulz WP. Experimental digital amputation and replantation. Plast Reconstr Surg. 1965;36:62–70.
13. Tamai S. History of microsurgery. Plast Reconstr Surg. 2009;124(6 Suppl):e282–94.
14. Malt RA, McKhann CF. Replantation of severed arms. JAMA. 1964;189:716–22.
15. Seidenberg B, Rosmak SS, Hurwittes ES, et al. Immediate reconstruction of the cervical esophagus by a revascularized isolated jejunal segment. Ann Surg. 1959;149:162.
16. Strauch B, Bloomberg AE, Lewin ML. An experimental approach to mandibular replacement: island vascular composite rib grafts. Br J Plast Surg. 1971;24:334–41.
17. McLean DH, Buncke HJ Jr. Autotransplant of omentum to large scalp defect with microsurgical revascularization. Plast Reconstr Surg. 1972;49:268–74.
18. Daniel RK, Taylor GI. Distant transfer of an island flap by microvascular anastomoses: a clinical technique. Plast Reconstr Surg. 1973;52:111–7.
19. Ueba Y, Fujikawa S. Vascularized fibula graft to neurofibulomatosis of the ulna: a 9-year follow up. Orthop Surg Traumatol. 1983;26:595–600.
20. Harii K, Ohmori K, Torii S. Free gracilis muscle transplantation, with microneurovascular anastomoses for the treatment of facial paralysis. Plast Reconstr Surg. 1976;57:133–43.
21. Watson JS, Craig R, Orton C. The free latissimus dorsi myocutaneous flap. Plan Reconstr Surg. 1979;64:299.
22. Yang G, Chen B, Gao Y, et al. Forearm free skin flap transplantation. Natl Med J China. 1981;61:139.
23. Song R, Gao Y, Song Y, Yu Y, Song Y. The forearm flap. Clin Plast Surg. 1982;9:21–6.
24. dos Santos lF. Retalho escapular: urn novo retalho livre microcirurgico. Rev Bras Cir. 1980;70:133.
25. Gilbert A, Teot L. The free scapular flap. Plast Reconstr Surg. 1982;69:601.

26. Swartz W, Banis J, Newton D, Ramasastry S, Jones N, Acland R. The osteocutaneous scapular flap for mandibular and maxillary reconstruction. Plast Reconstr Surg. 1986;77:530.
27. Nassif TM, Vidal L, Bovet JL, Baudet J. The parascapular flap: a new cutaneous microsurgical free flap. Plast Reconstr Surg. 1982;69:591.
28. Chen Z, Yan W. The study and clinical application of the osteocutaneous flap of fibula. Microsurgery. 1983;4:11–6.
29. Gilbert A. Vascularized transfer of fibula shaft. Int J Microsurg. 1979;1:100.
30. Pennington D'lai M, Pelly A. The rectus abdominis myocutaneous free flap. Br J Plast Surg. 1980;33:277.
31. Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. Br J Plast Surg. 1984;37:149–59.
32. Koshima I, Fukada H, Yamamoto H, Morigushi T, Soeda S, Ohta S. Free anterolateral thigh flaps for reconstruction of head and neck defects. Plast Reconstr Surg. 1993;92:421–8.
33. Kimata Y, Uchiyama K, Ebihara S, et al. Versatility of the free anterolateral thigh flap for reconstruction of head and neck defects. Arch Otolaryngol Head Neck Surg. 1997;123:1325–31.
34. Koshima I, Soeda S. Inferior epigastric skin flaps without rectus abdominis muscle. Br J Plast Surg. 1989;42:645–8.
35. Wei FC, Mardini S. Free-style flaps. Plast Reconstr Surg. 2004;114:910–6.

Anatomical Considerations of Free Flaps

2

L. Bianconi, L. Pierotello, G. Molteni, R. Pellini, and D. Marchioni

During the years, various authors proposed different classifications of flaps, based on composition, shape, and blood supply. Due to the complexity of reconstructive surgery, it is necessary a comprehensive classification in order to choose the best surgical option for each patient and improve the sharing of best practice among the surgeons.

Flaps are units of tissue that are transferred from a donor site to a recipient site, carrying its own blood supply to reconstruct functional units. Flaps can be classified according different features. Cormack and Lamberty proposed a comprehensive classification of flaps based on the *six C's*: circulation, composition, contiguity, conformation, construction, and conditioning [1–3].

2.1 Circulation

The blood supply of a flap can be random or based on known pedicles.

- Random skin flaps are based on the subdermal plexus vessel supply. They don't have a specific feeding vessel. Harvesting these flaps, the surgeon has to ensure an adequate vascularization considering the length to breadth ratio and its variation in the different body region (length to breadth ratio in face is 1:6, but 1:1 in lower limb).
- An axial pattern flap is a flap that includes a direct specific artery within its longitudinal axis.
- Fasciocutaneous flaps are based on one or more pedicles to fascia that runs in the intramuscular septa. Cormack and Lamberty classified fasciocutaneous flaps into four major types differentiated by the origin of the circulation (Fig. 2.1).

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L. Bianconi (✉)
Otorhinolaryngology-Head and Neck Surgery Department, University Hospital of Verona, AOUI Borgo Trento, Verona, Italy

L. Pierotello
Department of Otolaryngology, ULSS 6 Euganea, Cittadella, Italy

G. Molteni · D. Marchioni
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

R. Pellini
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

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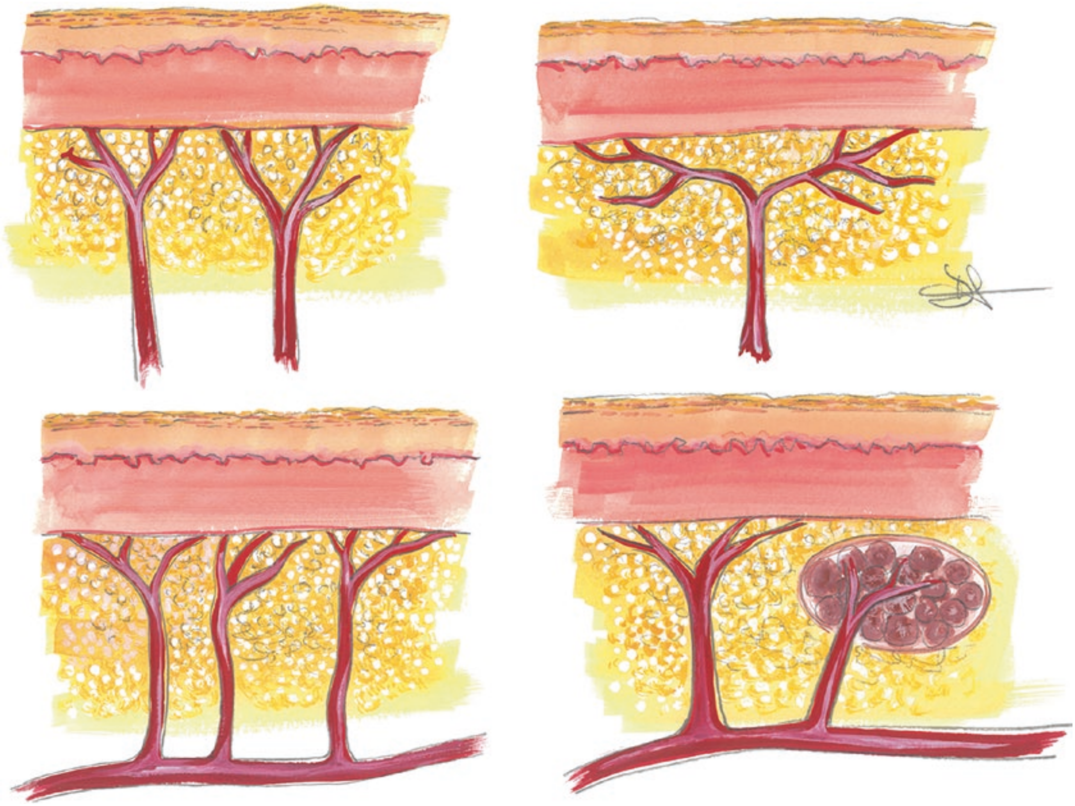

Fig. 2.1 The Cormack and Lamberty classification of fasciocutaneous flaps

- The Cormack and Lamberty classification of fasciocutaneous flaps [4].

Type A	A pedicled flap based on several vessels entering the base of the flap and following the long axis of the flap
Type B	A pedicled or a free flap based on a single perforator vessel at the level of the deep fascia
Type C	A pedicled or a free flap based on multiple small perforators originating from a deep artery and reaching the fascia along a septum between muscles
Type D	Fasciocutaneous flap that is harvested in with the adjacent muscle and/or bone with the same feeding artery

- Musculocutaneous flaps are based on perforator vessels that reach the skin through muscular tissue. According Mathes and Nahai classification, those can be divided in five types according the number on pedicles and their vascular dominance (Figs. 2.2, 2.3, 2.4, 2.5, and 2.6).
- The Mathes and Nahai classification of muscle and musculocutaneous flaps (1981).

Type 1	A single feeding vessel entering the muscle. For example, the tensor fascia lata
Type 2	A single dominant feeding vessel with smaller minor ones entering the muscle. For example, the gracilis
Type 3	Several dominant feeding vessels arising from different arteries. For example, the gluteus maximus
Type 4	Multiple segmental feeding vessels. For example, the sartorius
Type 5	One dominant feeding vessel and secondary segmental vascular pedicles. For example, the latissimus dorsi

Fig. 2.2 Type 1. The tensor of fascia lata muscle takes origin from the anterior iliac crest and inserts into the iliotibial tract and is supplied by the ascending branch of the lateral circumflex femoral artery

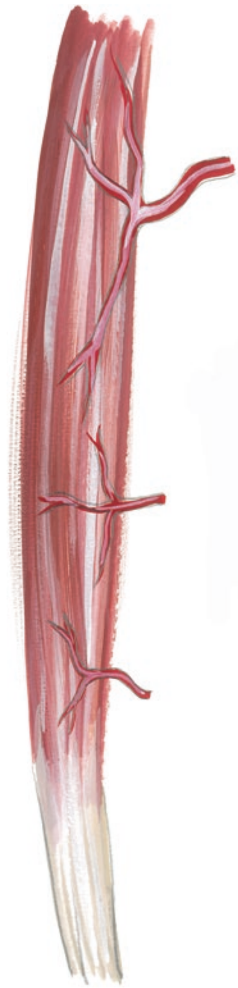

Fig. 2.3 Type 2. The gracilis muscle is a long muscle that is supplied by the adductor branch of the profound femoral vessels or the medial circumflex femoral vessels. In addition, two secondary pedicles can be found distally

2.2 Composition

Flaps can also be classified according to the composing tissue: cutaneous, fasciocutaneous, fascial, musculocutaneous, muscle, osseocutaneous, and osseous.

2.3 Contiguity

According to the anatomic region, flaps are distinguished in local, regional, and distant flaps.

- Local flaps: the tissue used for repairing lies adjacent to defect.
- Regional flaps: the flap is elevated from the same region of the body of the defect.
- Distant flaps: the tissue comes from a distant region of the body. These flaps can be pedicled or free depending on the detachment on the vascular pedicle. Free flaps are basically autotransplants, where the tissue is transferred using microsurgery to reestablish circulation making an anastomosis.

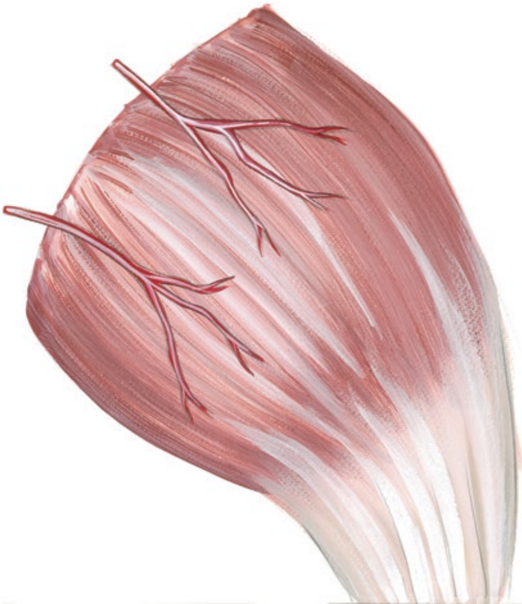

Fig. 2.4 Type 3. The gluteus maximus is supplied by the superior gluteal artery and by the inferior gluteal artery

2.4 Conformation

Flaps can have various shapes. Flaps are tailored and designed according to the dimension, shape, and localization of the tissue defect.

2.5 Construction

Method used for transferring flaps into the defect is another feature for classification.

- Advancement: local flaps moved along the direction of the pedicle. They use the skin elasticity for the filling of the defect.
- Rotation: local flaps rotated for the defect closure. The dimension of the flap should be wider than the defect for enabling the direct closure.
- Transposition: local flaps rotated or moved laterally. The harvesting of the flap creates a new defect that can be directly sutured.

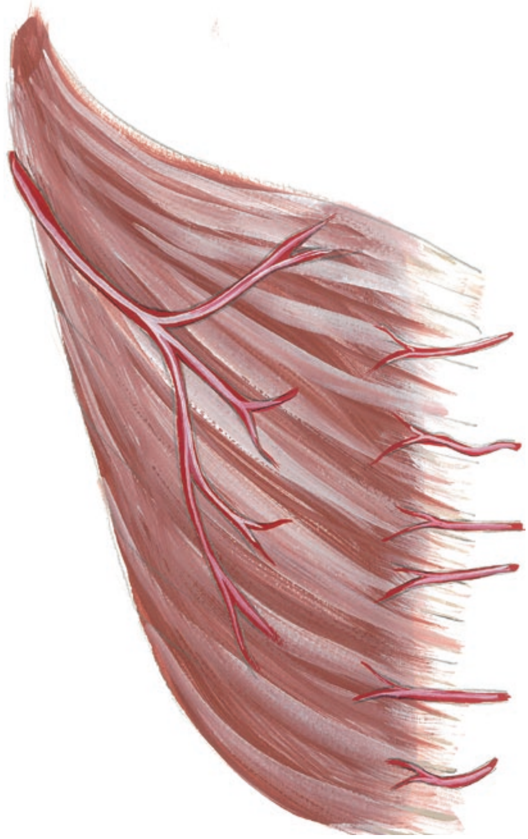

Fig. 2.5 Type 4. The latissimus dorsi muscle is supplied by two separate vascular systems. The main blood supply arises from the thoracodorsal artery via the subscapular artery. There is a secondary blood supply that arises from segmental perforating branches off of the intercostal and lumbar arteries

2.6 Conditioning

- Delay technique in a method to safely increase the amount of tissue to transfer. In the first stage of the procedure, a partial disruption of the blood supply to the flap is performed, and the rising is completed after 2–3 weeks.
- Flap prefabrication is based on the introduction of a vascular pedicle to a donor tissue that does not possess an axial blood supply. After a period of vascularization, the flap can be elevated and used for the reconstruction. Another technique based on tissue engineering is prelamination. The first step is the building of a three-dimensional composed structure on a reliable vascular bed. Once matured, this can be harvest.

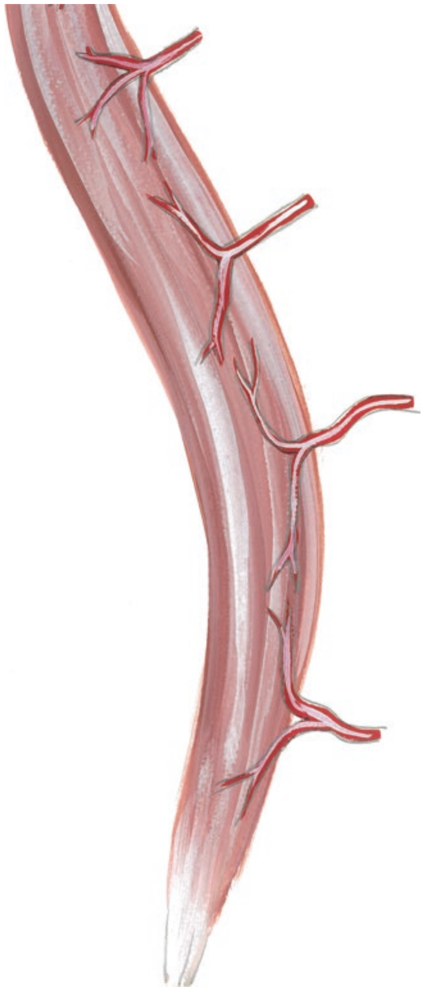

Fig. 2.6 Type 5. The sartorius muscle is supplied by multiple segmental pedicles. For each third of muscle, there is at least one vascular pedicle, often two pedicles, and occasionally three each arising from the superficial circumflex iliac artery, from the saphenous artery, or from the descending genicular artery

- Tissue expansion is a technique that allows the produce adequate skin for the coverage of the defect. The first procedure is the positioning of tissue expanders adjacent to the area of the lesion. When the generated tissue is enough for the defect closure, the excision of the lesion can be performed with the removal of the expanders.

2.6.1 Composite Flaps

The understanding on how conventional flaps receive their blood supply evolved in the concept of composite flaps. Major vessels traverse tissues providing blood flow and nutrition through their branches so the skin, muscles, bones, and connective tissue are linked by common vascular supplies. These vessels were identified to develop and harvest composite flaps formed by multiple tissue components. The whole flap has a single vascular supply that links all of these parts; in this way, all the components are depending on each other and sustain the flap itself. The dissection starts from the distal part at the subcutaneous tissue layer and proceeds to the source vessel to isolate it. Composite flaps are single units of various tissues or mono flaps, even if sometimes the distal parts can be divided following the branches of the vascular supply to fit the receiving site and allow better insertion and reconstruction. These flaps are suitable mainly to repair simple deficits (Fig. 2.7).

2.6.2 Combined Flaps

The particular characteristics of each flap can be joined to repair challenging defects where multiple tissue islands are required. Harii et al. first introduced the concept of combined flaps, when they first described a combined myocutaneous flap and microvascular free flap. The combination of flaps from a single donor site is frequently used, and each flap has its own independent blood supply. The first example described was a combination of both the skin territory of the latissimus dorsi musculocutaneous flap and the groin flap, which were connected together to form a bipedicled flap in which the vascularization was at opposite ends on the thoracodorsal and superficial circumflex iliac vessels. There are two major types of combined flaps that typically differ on the physical relationship of their tissue components yet remain similar; each of

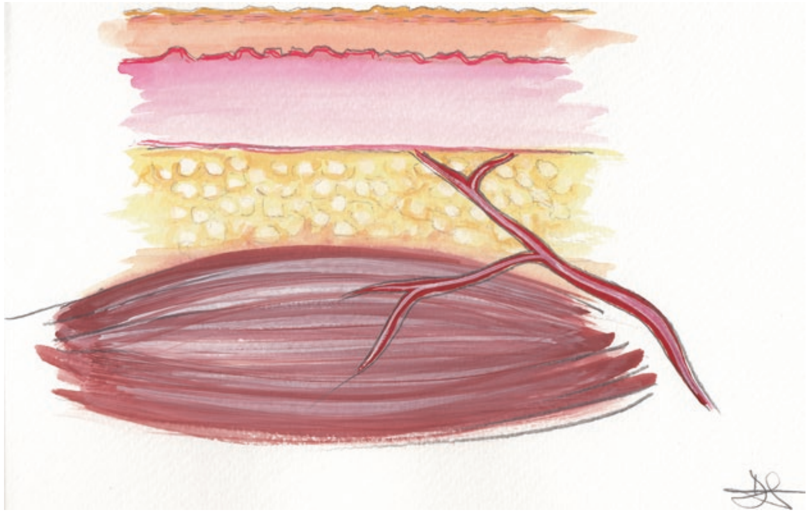

Fig. 2.7 Composite flaps. The blood supply for multiple tissues is granted by major vessels which can be used to harvest composite flaps. The whole flap has a single vascular supply, and all the components are depending on each other and sustain the flap itself

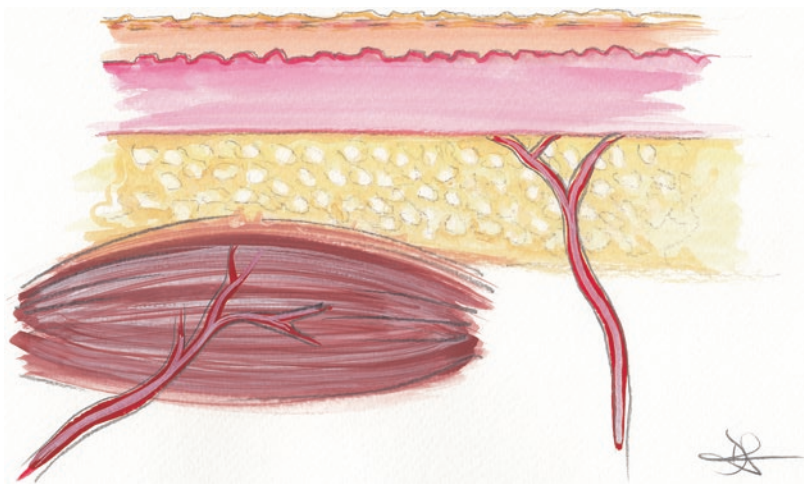

Fig. 2.8 Combined flaps. Multiple anatomical territories that are dependent due to a physical junction, yet each retains an independent vascular supply compose flap

their parts retains an independent blood supply. The conjoined flaps are a subtype of combined flap in which there are multiple anatomical territories that are dependent due to a physical junction, yet each retains an independent vascular supply. These flaps have shown to enhance the survival of either or both components, presumably due to a reversal of flow through the captured perforators (Fig. 2.8) [5, 6].

A particular type of combined flaps is the chimeric flaps, which are formed by multiple parts each with an independent vascular supply yet independent of any physical interconnection except where linked by a common vascular source. This type is exemplified by the subscapular system where fascial, muscle, and osseous flaps supplied by the thoracodorsal artery and circumflex artery allow a total freedom in flap planning and more than five dozens flap permutations (Fig. 2.9).

2.6.3 Vascular Pedicle

Reconstructive surgery is always focused on the selection of the better flap for each particular reconstruction, but the choice of the recipient vessels is also an essential step. In head and neck surgery, the selection and management of the

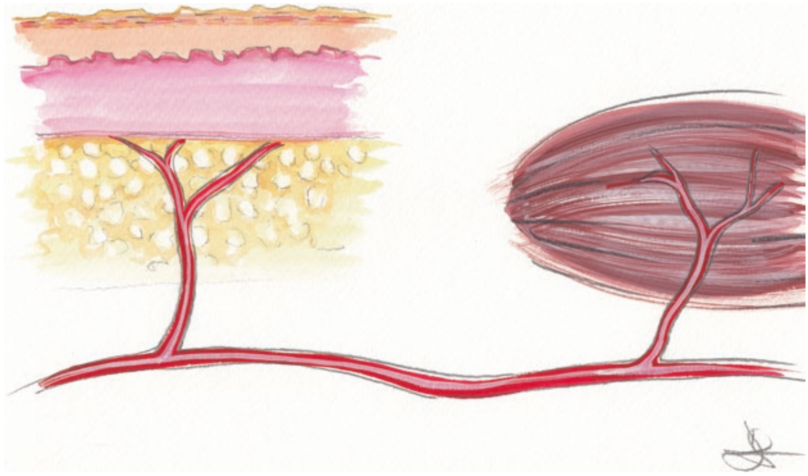

Fig. 2.9 Chimeric flaps. The flap is formed by multiple parts each with an independent vascular supply yet independent of any physical interconnection except where linked by a common vascular source

vessel positioning is more complex because the neck moves in three dimensions and can hardly be immobilized. Selection of recipient vessels is also impacted by many factors including location of the defect, quality of neck vessels (that can be different in previously treated neck), pedicle length depending on flap choice, and also anastomotic methods (end-to-end or end-to-side).

In head and neck reconstruction, the geometry of the pedicle is an independent parameter that has to be considered for the success of the surgery procedure. This can be defined as the positioning in the three-dimensional space of the vascular pedicle considering also the tension of the vessels and the redundancy. The movement of the head can produce stretching and kinking of the vascular pedicle and cause flap ischemia. For example, in free flaps, it's important to choose a vein and an artery that have the same axis, otherwise after the flap positioning the tensions can be higher on one structure or the other with the head movements. After inserting of the flap, before the anastomoses procedure, full-range movements of the head have to be tested in order to assess the geometry of the pedicle and avoid failure. It is also important to perform at least a partial flap insetting before microvascular anastomosis in order to avoid stretch or twist of the pedicle after microvascular step.

The most commonly used recipient arteries are branches of the external carotid artery (ECA) system: especially thyroid superior, facial, and lingual artery. Sometimes, anastomosis can be directly performed with the external carotid artery if needed. In vessel-depleted neck because of previous surgery or tumor infiltration of ECA, transverse cervical artery should be considered as a valid alternative for free flap reconstruction. The ideal artery should have a similar diameter to the donor artery and suitable length for the flap pedicle and should not involve tumor tissue. As we know from Poiseuille's law, what influences more a high vessel flow is its radius: the bigger is the vessel's radius, the higher is the flow. A higher vessel flow directly correlates to a higher flap circulations and thus probably flap survival.

Vein selection is usually related to anatomy of the pedicle and recipient vein available in each neck, because vein anatomy is more variable than arteries. Usually, in non-vessel-depleted neck, tributaries of the internal jugular vein are available in different diameters. Some surgeons prefer an end-to-end anastomosis with one of these branches, and some other surgeons prefer an end-to-side anastomosis directly with the internal jugular vein. In literature, it is not clear which is the safer solution [7, 8].

References

1. Wei F, Mardini S. Flaps and reconstructive surgery. Amsterdam: Elsevier; 2017.
2. Shokrollahi K, Whitaker I, Nahai F. Flaps. Practical reconstructive surgery. Stuttgart: Thieme; 2017.

3. Erovic BM, Lercher P. Manual of head and neck reconstruction using regional and free flaps. New York, NY: Springer; 2015.
4. Cormack GC, Lamberty BG. A classification of fascia-cutaneous flaps according to their patterns of vascularization. Br J Plast Surg. 1984;37(1):80–7.
5. Geoffrey G, Hallock GG. Further clarification of the nomenclature for compound flaps. Plast Reconstr Surg. 2006;117(7):151e–60e.
6. Hallock GG. The complete nomenclature for combined perforators flaps. Plast Reconstr Surg. 2011;127(4):1720–9.
7. Urken ML, Vickery C, Weinberg H, et al. Geometry of the vascular pedicle in free tissue transfers to the head and neck. Arch Arch Otolaryngol Head Neck Surg. 1989;115(8):954–60.
8. Hiller A, Davis J, SChulz S, et al. Recipient vessel selection in head and neck reconstruction. Eplasty. 2017;17:e42.

Microvascular Techniques

3

V. Valentini and M. Della Monaca

3.1 History

Alexis Carrel was the first to report a procedure for surgical repair in 1902 [1], and his work was honored with a Nobel Prize in 1912. In 1960s, Jacobsen and Suarez independently introduced the use of operating microscope in vessel repair. Since then, the vessel diameter became progressively smaller, and in 1966, Buncke and Schulz reported a successful rabbit ear replantation, requiring union of vessels 1 mm in size [2]. Finally, in 1968, Cobeett was the first to report the application of microsurgical vascular anastomosis in human for a toe-to-thumb replantation [3].

3.2 Setup

Since the first microsurgical anastomosis by Cobeett, research and publications have been increasing daily. Achieving over 98% of patency rates in the anastomosis of vessels of 1 mm in diameter is now common [4]. This is due to the introduction of dedicate and more precise instruments, availability of fine micro-sutures, and high-resolution and high-magnification microscopes. Besides technical innovations, it is undoubtable that the success of a microvascular anastomosis relies on a continuous laboratory training in order to get high level of personal technical skill. In fact, microsurgery techniques are based on simple sequential surgical maneuvers that are vital to follow in order to guarantee a high rate of success. It is important to understand that in microsurgery the margin for error is very low, and a strict adherence to a rigid scheme of rules is paramount. As quoted by Sabathy, it is essential "to cultivate a sense of discipline in performing every step correctly and never proceeding to the next step unless the previous step has been done to one's satisfaction." [4]

Before performing the micro-anastomosis, a series of distinct different phases has to be followed.

These phases can be summarized as follow:

– *Surgeon positioning and surgical area assessment.*
– *Selection of recipient vessels.*
– *Recipient and pedicle vessel preparation.*
– Surgeon positioning and surgical area assessment.

V. Valentini (✉) · M. Della Monaca
Department of Oral and Maxillo Facial Sciences, Policlinico Umberto I "Sapienza" University of Rome, Rome, Italy
e-mail: valentino.valentini@uniroma1.it

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The microsurgery procedure is usually performed after several hours from the surgical procedure onset; in order to diminish surgeon stress and fatigue, it is crucial to set the surgical area and to assume a correct work posture (Fig. 3.1).

For both surgeon and assistant, the ideal position for a micro-anastomosis is on the surface, not in a deep hole or under a bony shelf; neck extension on the operating table may be useful. Exposure must be adequate to access a good length of recipient vessel; careful use of self-retaining retractors or sutures to hold back the skin edge will further refine anastomotic exposure and access. An accurate hemostasis of the surgical field represents a keystone in performing a microsurgical procedure. A continuous trickle of blood is a very disturbing complication, and blood may stick on the vessel wall and become difficult to remove after a fibrin clot formation. A frequent irrigation and usage of moistened gauze may help to solve this problem. Vessels to be anastomosed should be parallel to the surgeon, and the vessel lumen should be on the same plane and clearly in view.

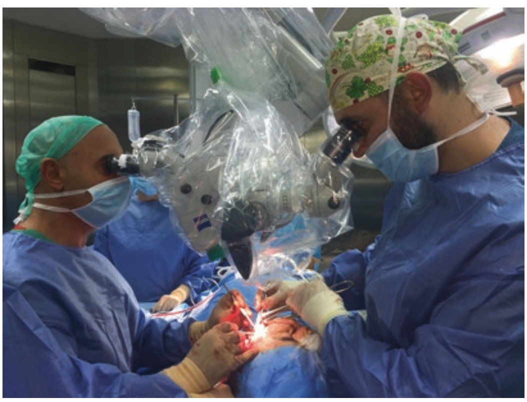

Fig. 3.1 Surgeons working position at microscope

The surgeon and assistant should be themselves opposite each other ideally sitting on height-adjustable stools and with their hands comfortably supported. Correct positioning of the hand is important to avoid tremor and reduce fatigue. The instruments should be held in the tripod pinch between the thumb, the index, and the middle finger stacked upon the ring and the little fingers. As suggested by Acland, this position led to control tremor and guarantee the best handling of microsurgical instruments (Fig. 3.2) [5].

3.3 Selection of Recipient Vessels

The recipient vessels should be as long as possible to permit them to reach closer the surface and to allow adequate exposure, access, and vessel rotation. The site of anastomosis should be chosen away from branches and venous valves, at least within the segment of vessels included in the clamp. Side arterial branches and tributary veins may act as restraints causing kink or alter anastomosis position before wound closure.

The recipient vein should be selected based on its caliber (up to twice as flap vein diameter). After its division, it is advisable to check for valves near the site of anastomosis that may cause drainage resistance. This may be accomplished through direct inspection under micro-

Fig. 3.2 Correct microsurgical instrument handling

scope magnification or through "a flush test." It consists in flushing the recipient vein with dilute heparinized saline through a blunt catheter in order to assess the ease of drainage. If high resistance or consistent backflow is encountered, a sacrifice of small vein segment containing the valves may be necessary. If this maneuver causes an excessive shortening of the vessel, another recipient vein should be selected. If there are no valves but high backflow is present, tying tributaries beyond the anastomosis site may represent a valid solution.

A good recipient artery should show a valid pulsation after its dissection, and a consistent spurt should to be present after its section. It is of paramount importance to not manipulate the artery excessively in order to not cause a spasm. The vessels have always to be handled by holding the adventitia and never by grasping the wall directly. During the dissection, it is useful to bath the vessel with warm saline, and if necessary and when a spasm is detected, irrigation with vasodilatation agents (papaverine 3%) may represent a good option (Fig. 3.3).

3.3.1 Pedicle and Recipient Vessel Preparation

In order to perform a correct anastomosis, the two vessel ends are to lie in the same plane and kept well approximated without tension. The choice of the best clamp to be used is based on vessel diameter and vessel wall characteristics (A vs. V clamp). The V clamps are usually used for both artery and veins, but in case of a slippery

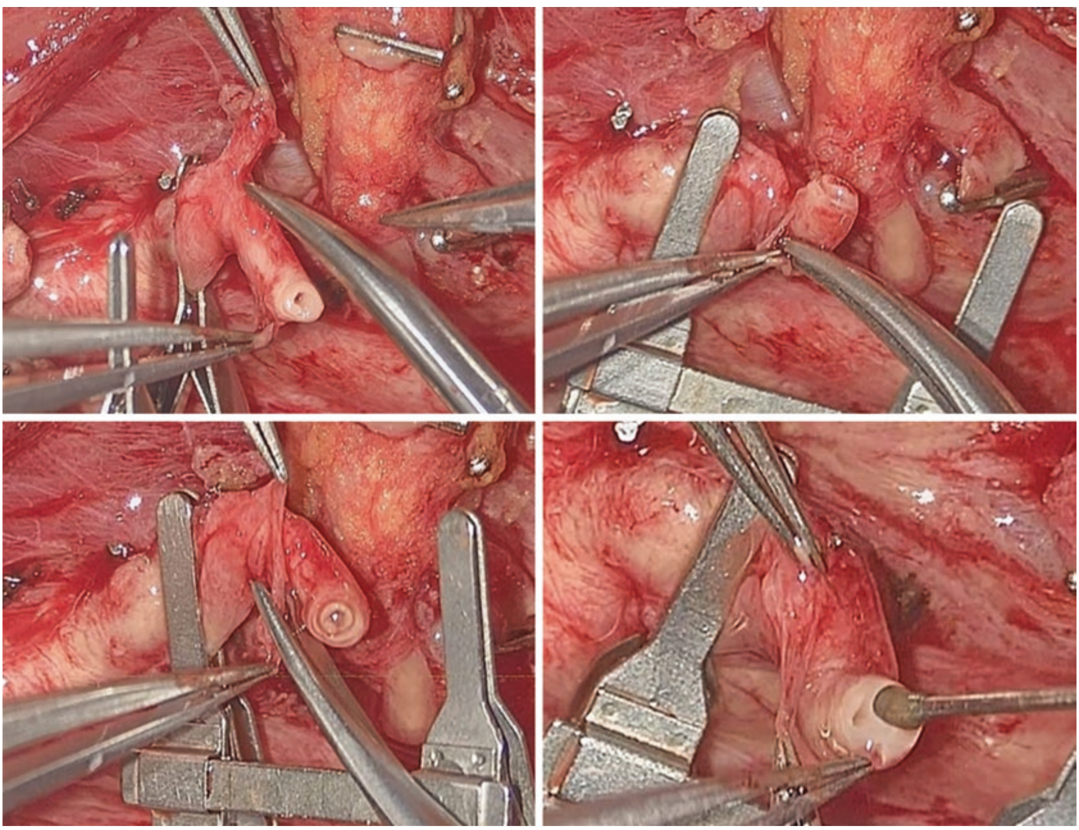

Fig. 3.3 Vessel preparation

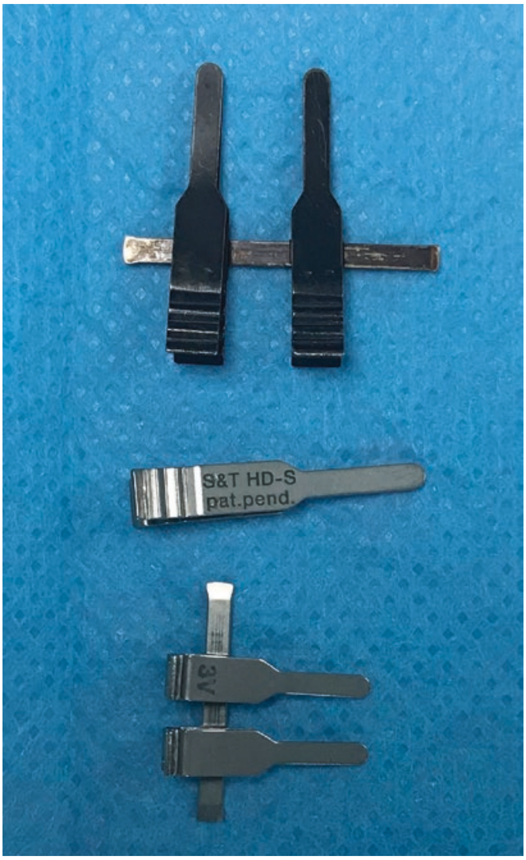

Fig. 3.4 Microsurgical clamps

vessels, the A clamps are needed. In applying the clumps, particular attention is to be paid to not snap the clamp onto the vessels (Fig. 3.4).

Before performing the anastomosis, adventitia need to be stripped. Fine trimming is required in order to clear see the vessel end and to prevent clot formation. The amount of adventitia removed should be extended up to 3–4 mm from the vessel ends. The procedure for the fine adventitia trimming follows three simple rules: grasp, pull, and cut. First of all, under high microscope magnification, the cleavage plane between the adventitia and tunica media is recognized. After that, the adventitia is grasped with Jeweler's forceps, pulled longitudinally, and cut with adventitia scissors (Fig. 3.5).

Vessels are irrigated with heparinized saline through a blunt catheter in order to flush out the residual blood inside the lumen between the clumps. Background material could be useful in performing the anastomosis (Fig. 3.6).

3.4 Vessel Anastomosis

3.4.1 General Principles

The outcome of a microvascular anastomosis relies on specific steps that have to be strictly followed and taken into consideration. These steps can be summarized as follow:

- Tie the knots with adequate tension in order to prevent stenosis and prevent leakage.
- Place the smallest number of sutures to achieve a leakproof anastomosis.
- Position the knots at equal distance apart.
- The bites on both sides must be equal, and the needle should cross exactly in a straight line.

3.4.2 Knot Technique

The needle should be held just behind its midpoint in a stable position (90° to the axis of the tips of a forceps). The needle should pass through the vessel wall at a perpendicular. This maneuver may be facilitated following simple tricks (Fig. 3.7).

Place the tips of the left-hand forceps on the underside of the tissue at the point where the needle will enter, and gently push the edge upward. With the right hand, bring the needle into contact with the tissue, and press downward. These movements create eversion. Pass the needle through. The needle must pass through the other side at a perpendicular, too. Bring the tip of the needle to the place where you intend to bring it out on the other side. Put the tip of your left-hand forceps on the upper surface of the tissue at the intended exit point. Press down with the left-hand

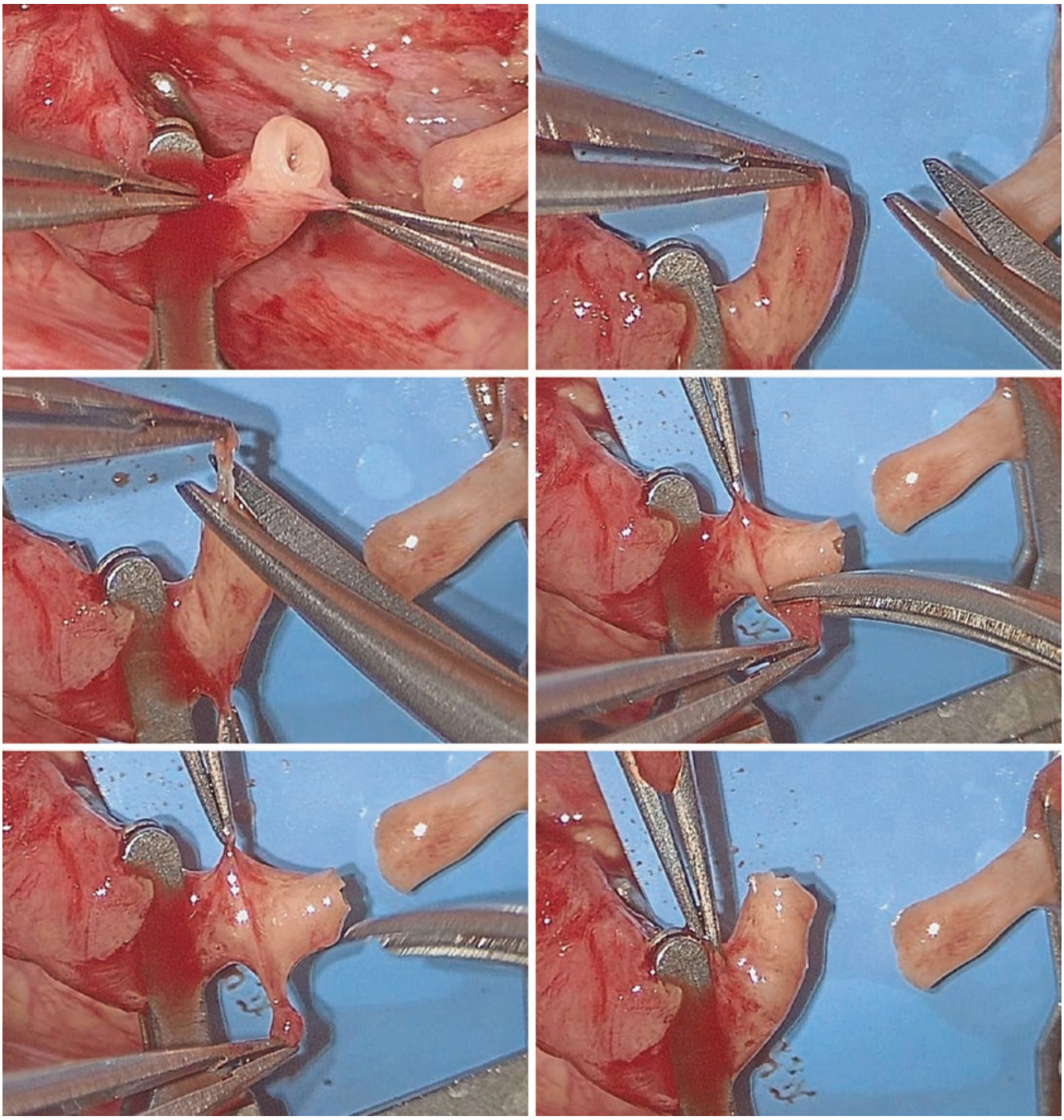

Fig. 3.5 Adventitia cutting

forceps, and push up with the needle to give you the correct eversion. The needle should cross exactly in a straight line (not diagonally).

Pull the needle through the tissue following the curve of the needle. It is crucial to avoid a "through stitch," in which both walls are caught by the suture (Fig. 3.8).

Before tying the knot, it should be useful to position the needle inside your visual field in order to quickly find it for the following sutures. When tying the knot, it should be simple to follow simple rules, especially for beginners.

1. Grab the thread with the *right* forceps at least one centimeter from the distal bite (three times the length of the suture tail).
2. Pull the thread toward the short-end tail of the suture.

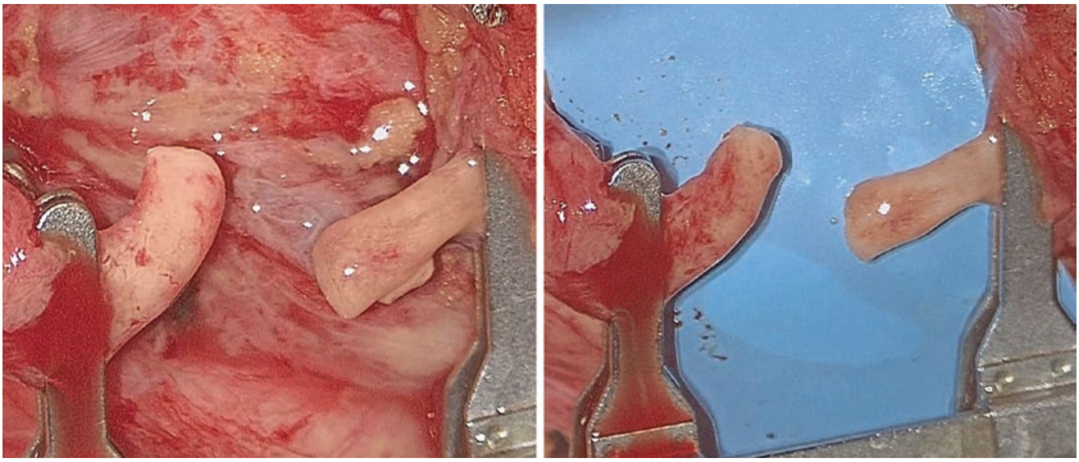

Fig. 3.6 Background material positioning

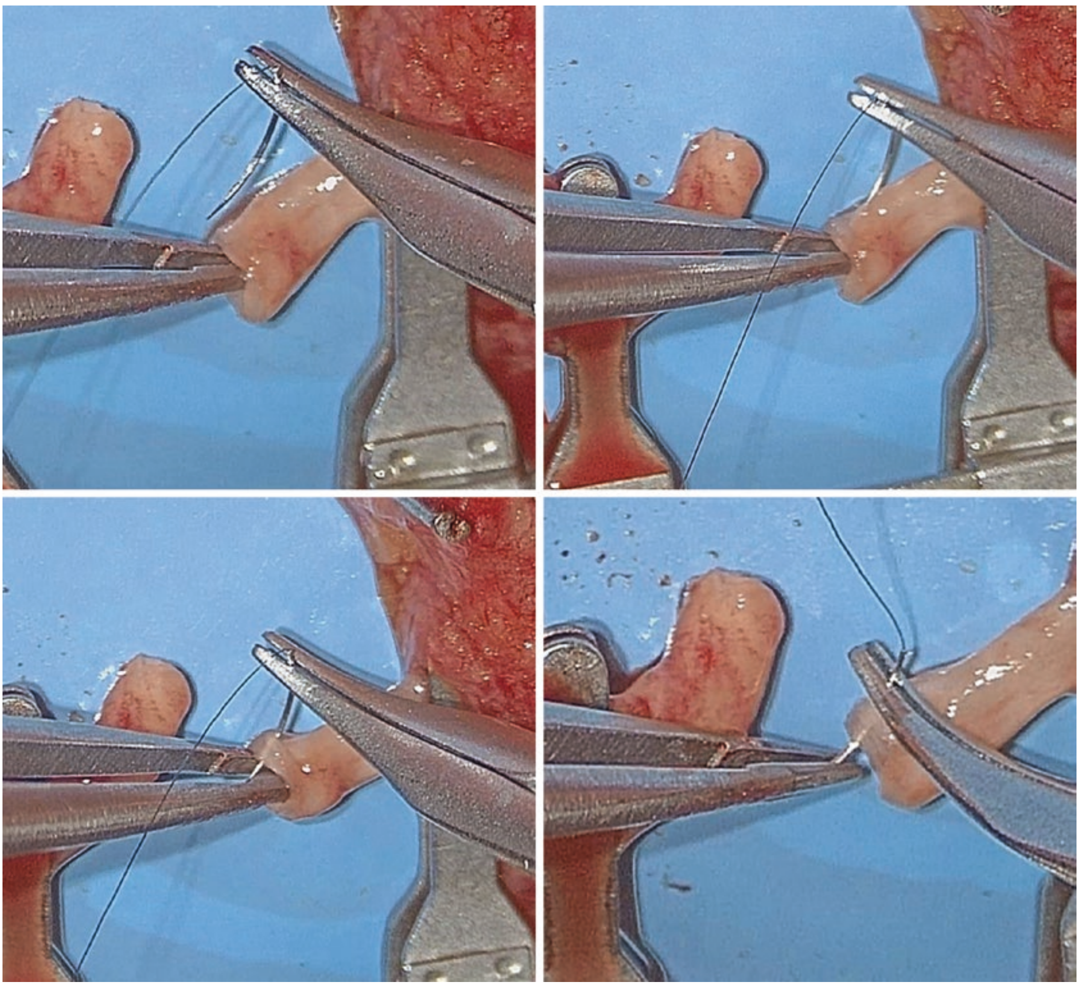

Fig. 3.7 Knot technique, first step

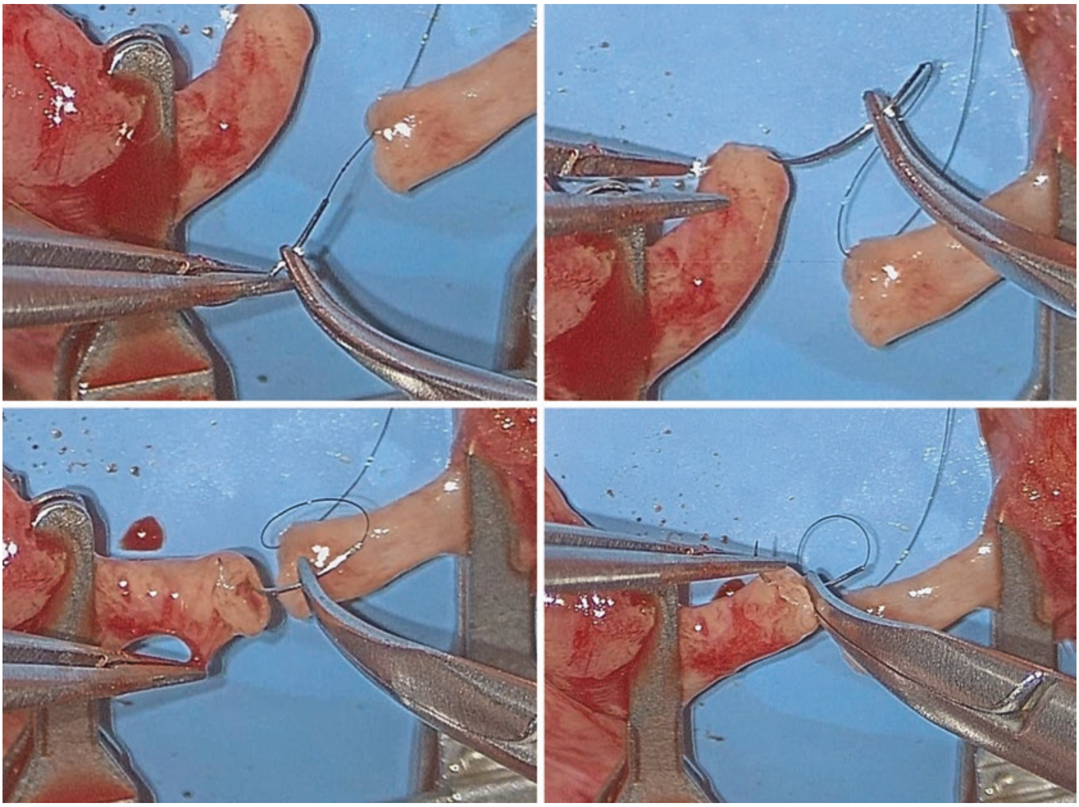

Fig. 3.8 Knot technique, second step

3. Position the tip of the *left* forceps close to the short-end tail.
4. Turn a double loop around the tip of the left forceps. Pay attention to make a clockwise turn and stay close to the short-end tail.
5. Grab the short end with left forceps and pull it through the loop. Tightening of the suture must be reasonable, because overtightening can lead to disruption of the vessel wall and damage of the intimal layer, which may result in the initiation of coagulation and thrombosis. On the other hand, too loose tightness of sutures may expose thrombogenic subintimal layers of the vessel wall, and patency of the anastomosis is also seriously threatened.

When this maneuver is correctly performed, the short-end tail has to be found 180° from its original position; steps 1–5 have to be repeated, but be careful to pick up the thread with the *left* forceps (step 1) and to make a single loop (anticlockwise turn) around the tip of the *right* forceps. Following these steps sequentially, a squared knot is done without crossing the hands during the procedure (Fig. 3.9).

3.5 End-to-End Anastomosis

The endtoend anastomosis using *interrupted sutures* is by far the most common method used. It is simple and appropriate for most arterial and venous anastomoses. A half-estimation, triangulation, or "back wallup" technique can be used to perform this anastomosis. In "half estimation" technique, the first two stitches are placed 180° apart.

They are placed at the superior and inferior aspects (or topmost portion and 180° apart) of the vessel circumference (Fig. 3.10).

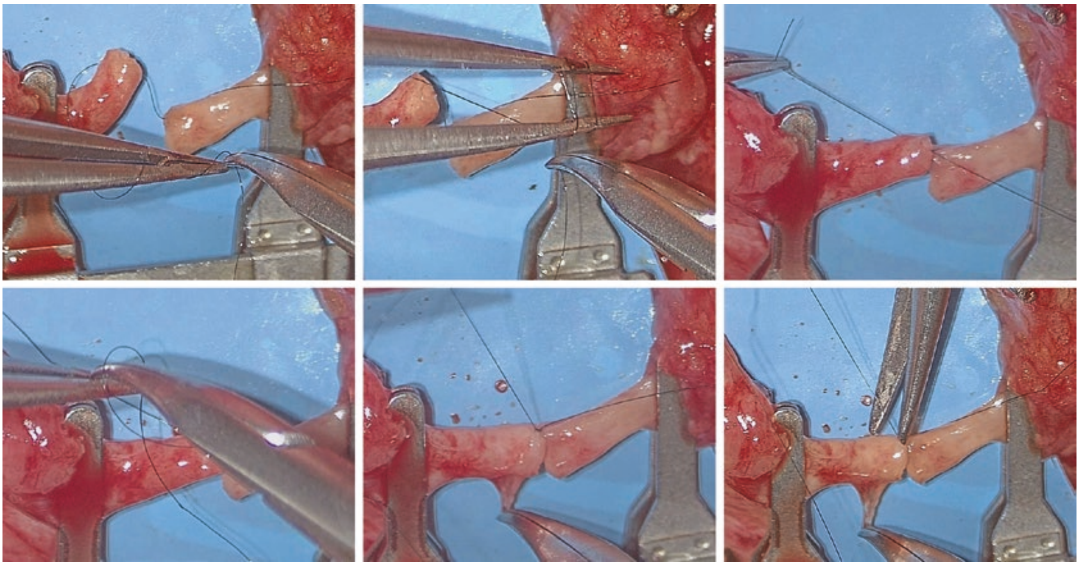

Fig. 3.9 Knot tightening

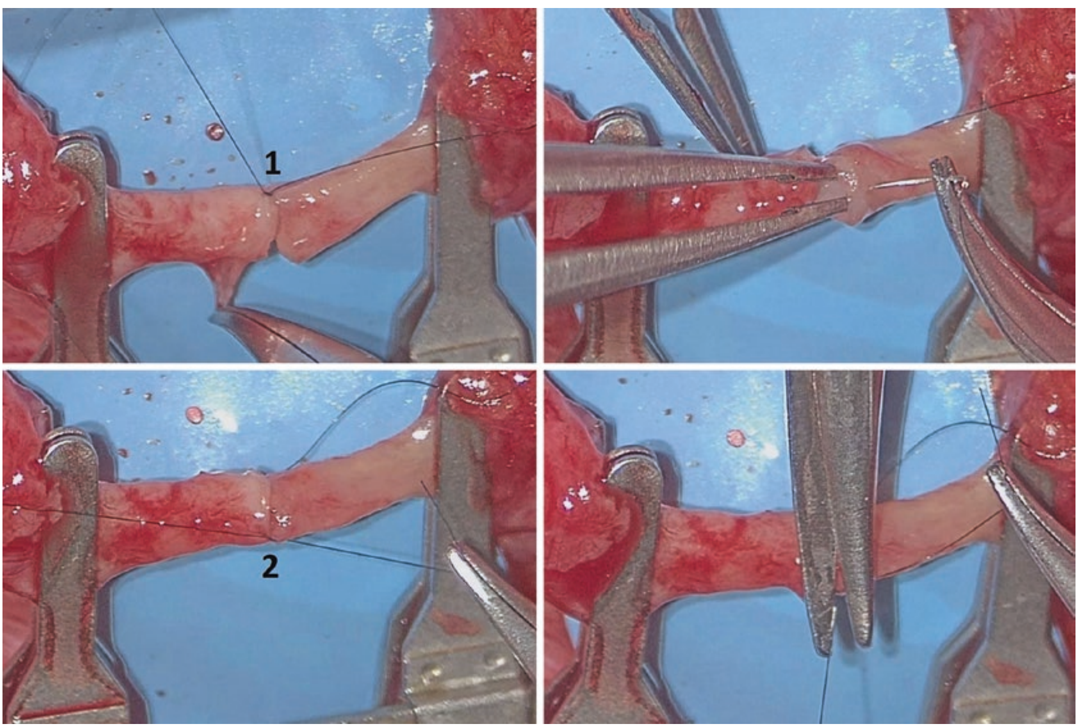

Fig. 3.10–3.13 End-to-end anastomosis: sequential stitch placing

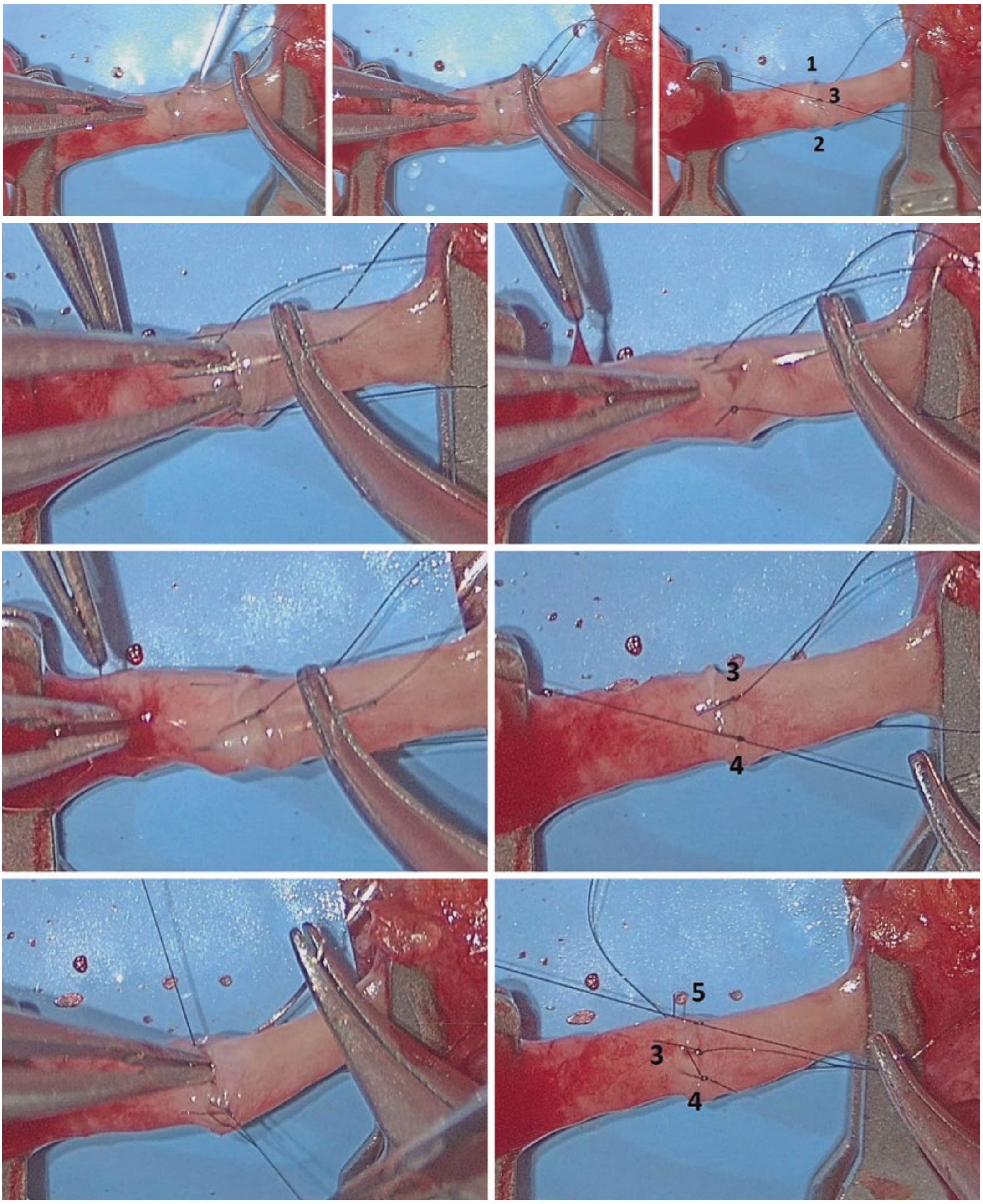

Fig. 3.10–3.13 (continued)

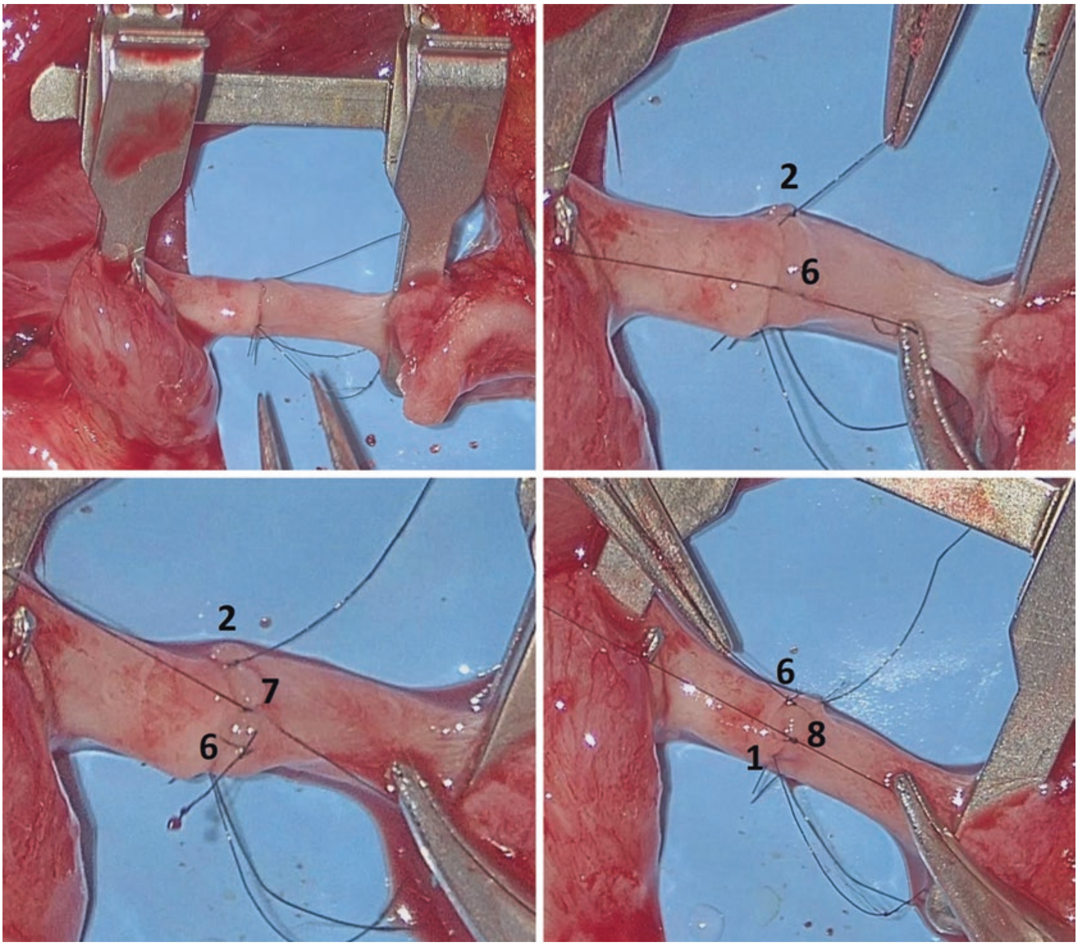

Fig. 3.10–3.13 (continued)

The third stitch is placed 90° between the first two stitches, at the half point (Fig. 3.11).

The fourth and fifth stitches are placed at 45 points between the third and the first two stitches (Fig. 3.12).

Following approximator clamp, flip the sixth stitches positioned at the 90 point, halfway between the first two stitches. The seventh and eight stitches are placed in a same fashion with fourth and fifth stitch placements (Fig. 3.13).

3.5.1 End-to-Side Anastomosis; Triangulation Technique

In triangulation technique [6] (Fig. 3.14), the stay sutures are taken 120° apart on the circumference; when the two stay sutured are tensioned, the two front edges come together and the back edges hang down. Following approximator clamp flipping, the third stitch is placed midway between the first two stitches. Sutures are placed in between the stay sutures, and the approximator clamp is turned over. The first suture is placed on the back edge exactly between the existing stay suture. By holding on the stay sutures, the anastomosis is completed. Surgeons may experience situation in which it is not possible to flip the clamp due to limited work space. In this situation, the "back wall-up" technique has to be employed. The first suture is as far away as possible. Then the back wall is sutured first upside down, taking care to space them appropriately apart. Once the back wall is completed, the front wall is completed.

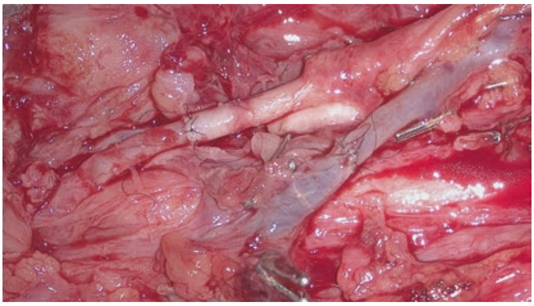

Fig. 3.14 Final appearance of the end-to-end anastomosis

Continuous suturing is a technique suitable for minimally size-discrepant vessels larger than 2–3 mm [7]. Two or three stay sutures are placed, leaving one suture end long. Starting from the last stay suture, running sutures are placed at regular intervals and tied to the next stay suture. Then the needle is passed under the vessel, and the double clamp turned over and suturing continued.

3.5.2 End-to-Side Anastomosis

When there is significant vessel size mismatch, vessel wall discrepancy, or a need to preserve the distal blood flow, as in a single vessel leg, end-to-side anastomosis is the technique of choice [8]. In order to perform an endtoside anastomosis, an arteriotomy or venotomy has to be made in the recipient vessel. Before performing the arteriotomy or venotomy, a good length of recipient vessel has to be dissected to allow placement of two clamps on either side of the arteriotomy/venotomy site. Twice the area of the proposed arteriotomy/venotomy site is cleared of adventitia. Different techniques are described for arteriotomy or venotomy. The cut may be triangular or elliptical or a simple longitudinal slit that will open up due to contraction of the muscle in the vessel wall. The hole should not have irregular edges as this may weaken the wall and facilitate thrombus formation. A single stitch is taken transversely at the anastomotic site and used as a stay suture. Holding this suture up, the vessel around the suture is excised using microvascular scissors. Alternatively, two precise scissor cuts are made from opposite directions at 45° to the vessel, in such a way that they meet exactly. Ideally this opening should not be longer than the diameter of the donor vessel as it will stretch once the clamps are released [9]. If jugular veins are chosen as recipient vessels for venous anastomosis, a side-biting Satinsky clamp can be used. It is enough to make a slit in such big veins and not necessary to excise a bit of the wall. The first to stitches are placed at proximal and distal ends of the arteriotomy/venotomy. It is essential to pay attention to not twist the flap vessel when these two first stitches are positioned. Then front and back wall are sutured. It may be easier to start from the back wall in order to gain better visualization and minimize the chance of a through stitch. Usually, the third stitch is positioned midway between the first two. The fourth and fifth stitches are then placed. These sutures have to be placed radially in order to avoid leakage at the ends (Fig. 3.6). Once the back wall is completed, the double clamps are turned over, and the same steps have to be followed for the front wall.

References

1. Carrel A. La technique operatoire des anastomoses vasculaires et la transplantation des visceres. Lyon Med. 1964;212:1561–8.
2. Buncke HJ, Schulz WP. Total ear reimplantation in the rabbit utilising microminiature vascular anastomoses. Br J Plast Surg. 1966;19(1):15–22.
3. Cobbett JR. Free digital transfer. Report of a case of transfer of a great toe to replace an amputated thumb. J Bone Joint Surg Br. 1969;51(4):677–9.
4. Sabathy RS. Vessels. In: Wei FC, Mardini S, editors. Flaps and reconstructive surgery. 2nd ed. Amsterdam: Elsevier; 2017. p. 310–22.
5. Acland RD. Practical manual for microvascular surgery. 2nd ed. St. Louis, MO: CV Mosby Company; 1989.
6. Carrel A. Anastomose bout a bout de la jugulaire et de la carotide primitive. Lyon Med. 1902;99:114–6.
7. Chen YX, Chen LE, Seaber AV, et al. Comparison of continuous and interrupted suture techniques in microvascular anastomosis. J Hand Surg Am. 2001;26:530–9.
8. Godina M. Preferential use of end–to–side arterial anastomoses in free flap transfers. Plast Reconstr Surg. 1979;64:673–82.
9. Wei FC, Tay SK. Principles and techniques of microvascular surgery. In: Gurtner GC, Neligan PC, editors. Plastic surgery. Amsterdam: Elsevier; 2012. p. 587–621.

Part II

Soft Tissue Flaps

4 Temporoparietal Fascial Flap

R. Pellini, A. Lambertoni, J. Zocchi, V. Manciocco, and G. Molteni

4.1 Anatomy of Temporoparietal Region

The temporal fossa is a lateral region of the scalp delimited anteriorly by the frontal process of the zygomatic bone, superiorly by the superior temporal line (i.e., a curved bony line of the squamous part of the temporal bone), and inferiorly by the zygomatic arch.

Before addressing the systematic anatomy, it's mandatory to describe the topographical disposition of tissues within this region. In particular, it is possible to identify five different anatomic layers proceeding gradually from the superficial skin to the deep temporal bone.

Externally, the skin and the subcutaneous tissues are the first two substantial anatomic layers.

The temporoparietal fascia (TPFF), a 2 to 4 mm thick layer of connective tissue, is located in a central position, lying just beneath the hair follicles and the subcutaneous tissue. It is hardly attached to the superficial soft tissues from which it's separated by a not so clearly defined and detectable cleavage plane. Here indeed, tissues are closely imbricated, and just an undefined layer of fat tissue defines the interface between the subcutaneous plane and the underlying temporoparietal fascia. The vascular network of the temporoparietal flap lies just within the temporoparietal fascia itself.

The TPFF is considered as a superior extension of the superficial musculoaponeurotic system (SMAS); superiorly, it continues as the galea aponeurotica, while inferiorly, just like the SMAS, it's firmly attached to the medial and lateral surface of the zygomatic arch.

Deep to the TPFF is located the temporalis muscle fascia, a thick white-pearl connective tissue taut above the temporalis muscle which attached inferiorly to the coronoid process of the mandible, passing deep to the zygomatic arch. The temporalis muscle fascia must be distinguished from the temporoparietal fascia: between these two, it lies a soft areolar tissue which allows a reciprocal natural mobility. On the opposite, the deepest soft tissues are firmly bound to the underlying bone. Above the temporal line, the temporalis fascia joints with the periosteum continuing superiorly as pericranium [1, 2]. A schematic representation of the anatomical layers of the temporal region is shown in Fig. 4.1.

R. Pellini (✉) · A. Lambertoni · J. Zocchi
V. Manciocco
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy
e-mail: raul.pellini@ifo.gov.it

G. Molteni
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

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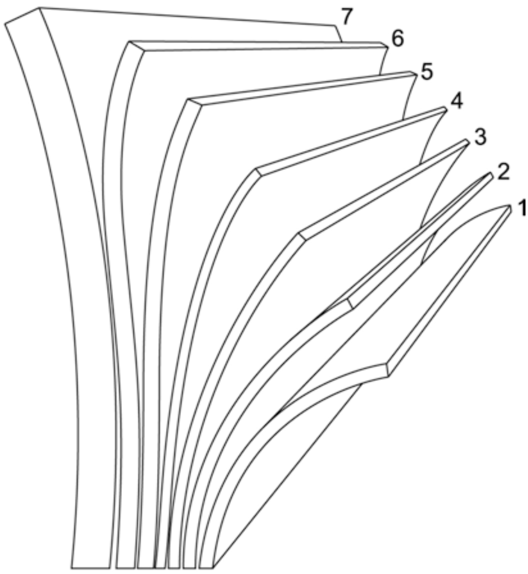

Fig. 4.1 Anatomical layers of temporal region. (1) Skin; (2) subcutaneous tissue; (3) temporoparietal fascia (superficial temporal vessel); (4) lose areolar tissue; (5) temporalis muscle fascia (middle temporal artery); (6) temporalis muscle (deep temporal artery); (7) bone with pericranium

4.1.1 Neurovascular Anatomy

The superficial temporal region is supplied by the superficial temporal vascular system that originates from the superficial temporal artery.

The superficial temporal artery (STA) represents, together with the internal maxillary artery, a terminal branch of the external carotid artery. The latter runs deep in the parotid gland where it ascends and just behind the neck of the mandible divides into its two terminal arteries.

While the internal maxillary artery runs forward directed to the infratemporal fossa, the STA (which measures a diameter of about 1.90 mm at its origin) rises about 5 mm in front of the tragus, ascends upward lying posteriorly to the ramus of the mandible and reaching the temporoparietal fascia. In the second superficial tract of its course, the artery is accompanied by the corresponding vein and the auriculotemporal nerve. It runs up toward the temporal region, crossing the posterior third of the zygomatic arch and going beyond it for about 4 cm, where it divides into its two terminal branches: the frontal (anterior) and the parietal (posterior). These two arteries have similar size, with the frontal branch that seems to be less variable than the parietal [3]. The superficial temporal artery supplies the skin and the muscles of the same side of the face and scalp, the parotid gland, and the temporomandibolar joint.

The frontal branch has a winding course toward the frontal region proceeding in an anterosuperior direction; it is usually slightly larger than the parietal one (1.2 and 1.1 mm, respectively) [4], and it anastomoses with the corresponding branches of the opposite side and with branches from the ophthalmic artery. Conversely, the parietal artery curves upward and backward, toward the vertex, until it anastomoses with the contralateral one and with the posterior auricular and the occipital arteries.

Before ending in these terminal vessels, the superficial temporal artery gives several collateral branches: the transverse facial artery, the zygomatico-orbital artery, the middle temporal artery, and anterior auricular arteries. The first one originates deep into the parotid gland, just below the zygomatic process of the temporal bone, and it runs forward horizontally lying over the masseter; once emerged from the gland, it is accompanied by branches of the facial nerve. It supplies the parotid gland and its duct, the masseter muscle, and the skin.

The zygomatico-orbital artery branches superiorly and runs horizontally along the superior border of the zygomatic arch, between the two layers of the temporal fascia, reaching the lateral orbital angle. It anastomoses with branches from the ophthalmic artery.

The middle temporal artery originates just above the zygomatic process and supplies the temporalis fascia anastomosing with branches from deep temporal arteries, which originate from the internal maxillary artery. These different vascularized networks [5], which supply separately the superficial temporoparietal fascia and the temporalis fascia, represent a crucial anatomic feature which makes this flap ideal when requiring a highly vascularized tissue in the surgical bed.

The last arteries, the auricular branches, arise posteriorly and bring blood flow to the lateral surface of the auricle and to the external acoustic meatus.

A widespread venous network across the scalp forms, at the level of zygomatic arch, the superficial temporal vein, which runs down close to the artery. It may be single or duplicate.

In most cases, it runs superficially to the artery, though in 20–30% of the cases the vessel diverges from the artery and runs up to 3 cm posteriorly [6, 7].

It is remarkable how the venous drainage of the region seems to consist in the superficial temporal vein and the posterior auricular venous network [8]. However, this anatomical pattern seems to be purely descriptive, and actually variations in temporal venous drainage have been described in literature. Indeed, authors have reported how the superficial temporal vein does not appear to be always the dominant vessel and is not constant. Sometimes, the posterior auricular vein represents the main drainage of the region. Particularly, they described three different patterns of venous vascularization: type 1 consists in a dominant superficial temporal vein, type 2 with a posterior auricular vein predominant, and finally type 3 with both the venous vessel equally represented. In author's opinion [8], it's advisable to assess these different anatomical conditions preoperatively with angiography, in order to avoid complications during the microsurgical phase of the free flap technique: a slight venous vessel will not be suitable for an appropriate vascular microanastomosis and would not be able to guarantee the venous drainage of the flap [8] efficaciously.

There are several nervous branches lying in the temporoparietal region that the surgeon may encounter during the dissection. The auriculotemporal nerve is a sensory branch from the trigeminal nerve, runs within the superficial temporoparietal fascia close to the vascular pedicle, and gives sensitivity to the skin of the region dividing into its superficial temporal twigs.

Another important nervous structure of the region is the temporal branch of the facial nerve. The temporal ramus of the facial nerve is the first of the five terminal branches arising from the main trunk of the nerve, deep within the parotid parenchyma. The temporal nerve runs upward and leaves the parotid gland by its superomedial surface. It crosses the zygomatic arch in the middle, where it assumes a more superficial course [9], and lying in a superficial subcutaneous layer supplies the facial muscles [3]. The temporal ramus has an oblique direction, following a virtual line (Pitanguy line) which goes from 0.5 cm below the tragus to 1.5 cm above the lateral extremity of the eyebrow; it is at risk of injury during the anterior dissection of the flap.

4.2 Flap Harvesting

4.2.1 Preoperative Management

Many factors could influence the feasibility of reconstruction using TPFF. First of all, it's mandatory to exclude preoperatively all those factors that could have compromised the vascular pattern of the temporal region, that is to say, history of previous radiation to the region, previous local surgery, external carotid embolization or ligature, and autoimmune arteritis (e.g., giant cell arteritis). All these anamnestic risk factors represent a contraindication to the use of this flap.

For these reasons, when projecting the surgical plan, it's fundamental to assess preoperatively the entity of the blood flow through the vascular pedicle using a Doppler ultrasonography. Therefore, this precaution allows to exclude any anatomical variants of the superficial temporal vessels and to ensure the vascular supply of the TPFF.

In literature, some authors have proposed how a preoperative angiography could be useful to evaluate the exact pattern of venous drainage of temporal region, thus avoiding the use of TPFF as a free flap when the superficial temporal vein seems not to be the dominant vessel [8].

A good recommendation, although not indispensable, is to shave accurately the hair of the temporal region preoperatively. Shaving could be limited just to the incisional area.

It is advisable to identify and drawn preoperatively the course of the vascular network of the region. The course of the arterious vessel will be easily identified through a meticulous palpation of the region or by the use of Doppler ultrasonography. For what concern the course of the venous vessel, in our experience, a useful tip is to apply a firm pressure at the level of the vascular pedicle in the pretragal region in order to cause a blockage to the venous drainage. This will consequently bring to a swelling of the venous vessel immediately appreciable beneath the skin, making the course of the vein clearly evident.

In conclusion, these few and easily reproducible suggestions may be sufficient for an accurate preoperative evaluation and will make the dissection easier.

4.3 Surgical Steps

4.3.1 Step 1: Surgical Incision

A variety of surgical incision has been described [2]. The author prefers the Y-shaped incision which allows a better exposition of the surgical field when harvesting the flap. The incision begins at a pretragal level and ends at the level of the temporal line. It's possible to find the vascular pedicle anteriorly to the surgical skin incision (Fig. 4.2) [1]. It's mandatory to perform the cutaneous incision with cold scalpel technique rigorously, in order to avoid any damage of the pedicle itself and to hair follicles through electric scalpel technique.

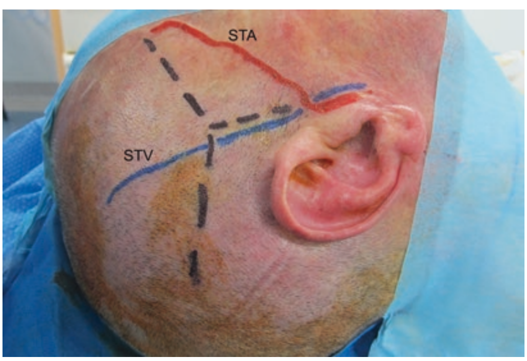

Fig. 4.2 Surgical incision and vascular network course. *STA* superficial temporal artery, *STV* superficial temporal vein, *black-dotted line* surgical incision

4.3.2 Step 2: Scalp Flap

The dissection can proceed now elevating the anterior, the posterior, and the superior scalp flap. A particular attention must be paid during this phase to avoid injury to the overlying hair follicles, in order to prevent the risk of postoperative alopecia; thus, a delicate dissection in a subfollicular plane is mandatory, possibly leaving a thin layer of subcutaneous fat on the overlying dermis. Another potential pitfall during this phase is the risk of injury of the vascular network which lies within the underlying temporoparietal fascia; thus, it's preferable to use cold surgical instruments rather than bipolar electrocautery, which must be limited to control hemostasis in case of small bleeding.

During this phase, it's advisable not to overcome the anterior limit of the flap dissection defined by the course of the frontal branch of the facial nerve, thus avoiding any injury to this latter.

At the end of the dissection, a good enough exposition of the temporoparietal fascia will be obtained (Fig. 4.3).

4.3.3 Step 3: Pedicle Dissection

The dissection proceeds at the pretragal region with the identification of the vascular pedicle Fig. 4.4 shows the superficial temporal artery (red strip) and the vein (blue strip) immediately close to it. The vein lies in a more superficial layer, while the arterious winding pedicle runs deep arising from the parotid parenchyma.

In this region, superficial and deep plans are firmly and intimately imbricate: anatomical plans can be somewhat difficult to identify and respect, so that the dissection must be delicate and accurate.

In order to obtain a much longer length of the vascular pedicle, it's possible to continue the dissection of the temporal vessels downward along the tragal region [2].

4.3.4 Step 4: Flap Harvesting

Firstly, the surgeon will identify and ligate the major arterious and venous vessel at the level of the superior temporal line, and then, he proceeds with the upper incision of the temporoparietal fascia.

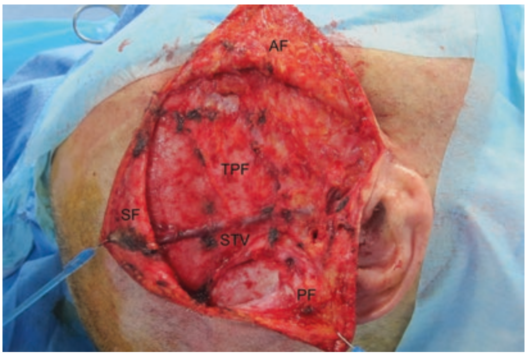

Fig. 4.3 Skin scalp flap and surgical field. *STV* superficial temporal vein, *TPF* temporoparietal fascia, *AF* anterior flap, *SF* superior flap, *PF* posterior flap

Consequently, once the frontal branch of the facial nerve is identified, the anterior incision of the fascia can be performed immediately posteriorly to its course. The location of the posterior incision is variable depending on the surgical needs, and it will be performed posteriorly to the vein, thus avoiding damage to the vascular network.

The deep landmark plane for the surgeon is the temporalis fascia: it's better to start the dissection superiorly, at the level of the temporal line toward the vascular pedicle. The dissection will be conducted through the avascular areolar tissue which separates the two fascial layers.

The definitive dimension of the flap is about 12 × 10 cm, with a thickness of 2–4 mm (Fig. 4.5).

Figure 4.6 shows the temporoparietal fascial flap harvested and isolated with its vascular pedicle and its placement in the definitive surgical bed with arterious and venous microanastomoses.

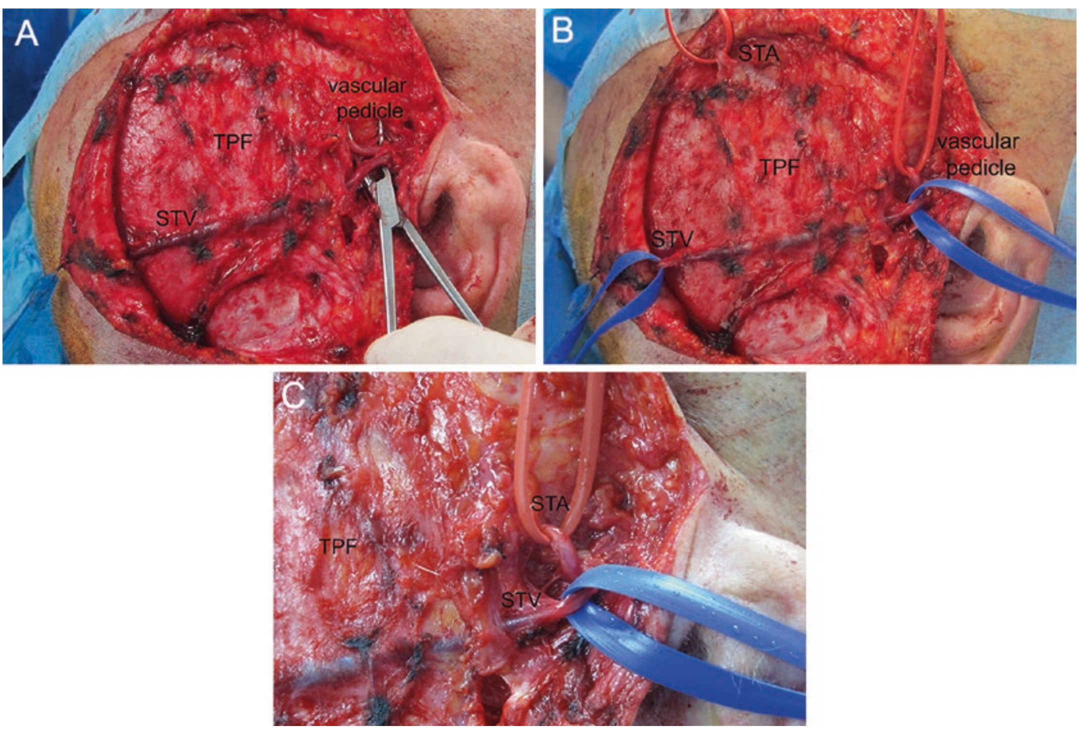

Fig. 4.4 Surgical dissection of vascular pedicle. *STV* superficial temporal vein, *STA* superficial temporal artery, *TPF* temporoparietal fascia

4.4 Analytical Factors and Technical Considerations

The donor-site morbidity and the potential complications related to this surgical technique are relatively less severe than in other conditions of flap harvesting. Below, the main complications potentially related to the procedure are reported.

At first, the major specific surgical-related risk is the postoperative alopecia of the incisional area; this may be provocated by a too superficial surgical dissection, which do not respect the correct dissection plane, that is to say, the subfollicu-

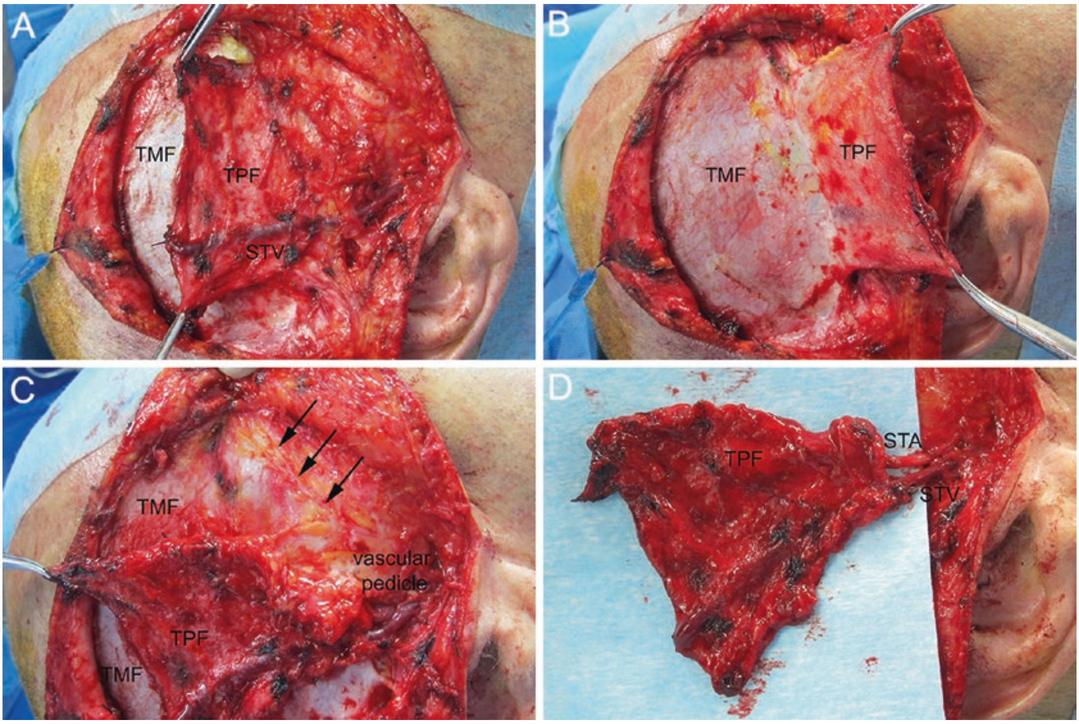

Fig. 4.5 Flap harvesting. *TMF* temporalis muscle fascia, *TPF* temporoparietal flap, *STV* superficial temporal vein, *STA* superficial temporal artery, *black arrows* course of temporal branch of facial nerve

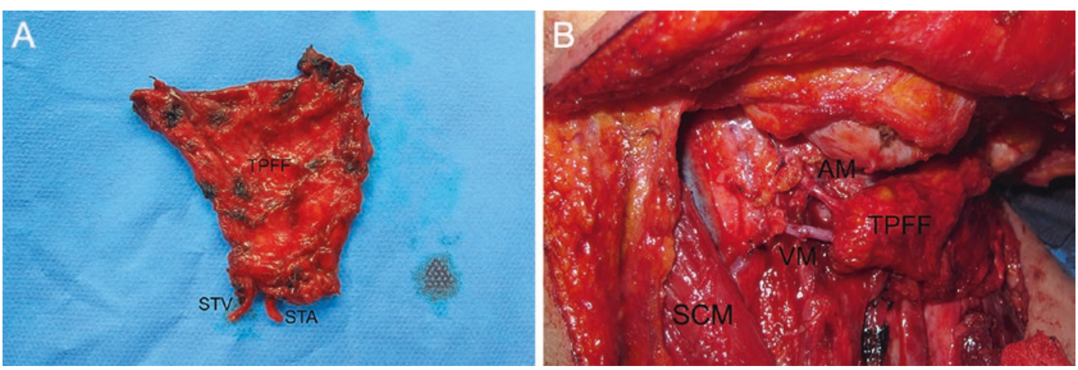

Fig. 4.6 (**a**) Temporoparietal fascial flap (TPFF) isolated with its vascular pedicle; *STA* superficial temporal artery, *STV*, superficial temporal vein. (**b**) TPFF positioned in the surgical bed; *AM* arterious microanastomoses, *VM* venous microanastomoses

lar one. An excessively superficial dissection brings inevitably to hair follicles injury and thus to secondary alopecia. The secondary alopecia has been described to develop about 2 cm around the surgical incision. As mentioned before, it's advisable to conduct the surgical dissection by cold instruments instead of bipolar electrocautery in order to avoid heat injury to the tissues.

The anatomical correlation with the frontal branch of the facial nerve imposes a limitation in the anterior dissection of the flap, and it's advisable to accurately identify the facial nerve, thus avoiding to damage it. In this sense, Pitanguy line can represent a reliable reperee.

Hematoma/seroma formation and wound healing problems are other general complications potentially related to the surgical procedure [2]. To avoid this issue, once the procedure of flap harvesting is complete, a suction drain is placed in the surgical bed, and the temporal surgical incision is closed with a layered technique.

The temporoparietal fascial flap (TPFF) could be used in a variety of head and neck reconstructions [10–12]. Indeed, it presents some essential features which make it a suitable and reliable flap in several reconstruction conditions. In literature, authors have described a wide variety of surgical defects that have been successfully reconstructed using this flap, that is to say, defects of oral cavity [13, 14], ear deformities, skull base defects, nasal reconstruction [14], tracheal defect, pharyngocutaneous fistula [12], tracheal reconstruction [2], facial defects [15], eyebrow/mustache/scalp's hair reconstruction [16, 17], and so on. A summary of the uncontested characteristics intrinsic to this flap is given below.

Firstly, its intrinsic pliability and thinness made this flap strategic and versatile in different kind of head and neck reconstruction. Among the multitude of human flaps described, the temporoparietal one seems to be the thinnest known and currently used in the human body [18]. This feature makes it ideal in reconstruction of small and irregular concavities, without an exaggerated distortion of the natural anatomy of the site to be reconstructed.

Another significant characteristic is its potentiality of being a composite flap. Depending on the reconstruction needs, it is possible to raise with the flap different layers of the temporal region based on the temporal vessels; thus, different tissues such as small skin island, deep temporal fascia, temporalis muscle, or calvarial bone can be included in the flap when required [2].

Thus, in order to increase the thickness and the strength of the flap and to improve the vascular support intrinsic to the flap, it is possible to harvest the temporal fascia with the overlying tissues; in these cases, the deep surgical dissection plane will be the temporal muscle as shown in Fig. 4.7.

One of the major features of this flap is its intrinsic and extremely high vascularity, which provides a generous blood supply to the surgical bed. This condition is certainly guaranteed by the double and well-represented vascular network which consists in independent vascularization of the superficial temporoparietal fascia and the deeper underlying temporalis fascia: the first one is nourished by branches from the superficial temporal artery, while the second by the middle temporal artery. This robust vascular supply makes it excellent when coverage of exposed cartilage or bone is needed or when dealing with suffering and damaged tissues, such as in condition of chronic infections, previous radiation, or devitalization [2, 18].

Another uncontested benefit is the minimal donor-site morbidity as no major complications

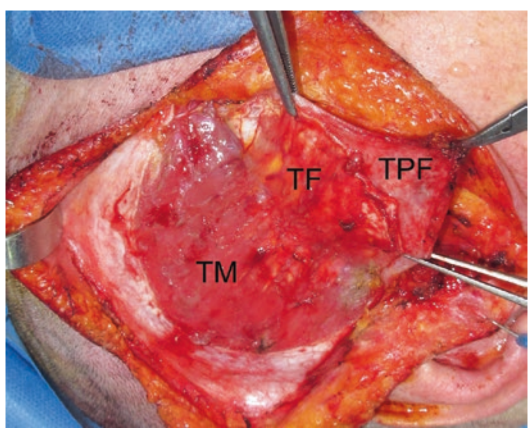

Fig. 4.7 *TPF* temporoparietal flap. *TF* temporalis fascia. *TM* temporalis muscle

has been described; as explained before, the potential complications of the temporal region, once the flap is harvested, are rare and more tolerable if compared to donor-site morbidity described for other flaps [19].

Despite all the advantages mentioned before, it's crucial to underline one of the main limitations of this fascial flap represented by the shortness of the pedicle. Thus, although it's possible to slightly extend its length with the dissection in the pretragal region, this flap is not recommended when surgical needs impose a significant length of the vessel to perform an adequate microanastomoses during the reconstruction phase.

In conclusion, all the features mentioned before, such as the pliability, the thinness, the high vascularity, the minimal donor-site morbidity, and the capability to be used as free or pedicle flap and to be a composite flap, make it one of the most versatile reconstructive option and an extremely useful tool for the surgeon in head and neck reconstruction.

References

1. Urken M. Atlas of regional and free flaps in head and neck reconstruction. New York, NY: Raven Press; 2011.
2. Demirdover C, et al. The versatile use of temporoparietal fascial flap. Int J Med Sci. 2011;8(5):362–8.
3. Standring S. Gray's anatomy: the anatomical basis of clinical practice. 40th ed. New York, NY: Churchill-Livingstone; 2008.
4. Cormac GC, Lamberty BGH. The arterial anatomy of skin flaps. New York, NY: Churchill Livingstone; 1986.
5. Acland R, Abul-Hasan H, Ulfe E. Superficial and deep temporal fascia flap: an anatomic approach. Videotape presentation at the Annual Meeting of the American Society of Plastic and Reconstructive Surgeons. Las Vegas, NV, 12 Oct 1983.
6. Rose EH, Norris MS. The versatile temporo-parietal fascial flap: adaptability to a variety of composite defects. Plast Reconstr Surg. 1990;85:224.
7. Tegtmeier RE, Gooding RA. The use of fascial flap in ear reconstruction. Plast Reconstr Surg. 1977;60:406.
8. Lopez R, et al. Description and variability of temporal venous vascularization: clinical relevance in temporoparietal free flap technique. Surg Radiol Anat. 2013;35:831–6.
9. Lettieri S, et al. Frontal branch of the facial nerve: galeal temporal relationship. Aesthet Surg J. 2008;28(2):143–6.
10. Lai A, et al. Temporoparietal fascial flap in orbital reconstruction. Arch Facial Plast Surg. 2000;2(3):196–201.
11. Park C, et al. Use of an expanded temporoparietal fascial flap technique for total auricular reconstruction. Plast Reconstr Surg. 2006;118(2):374–82.
12. Fabrizio T, et al. Repair of the pharyngocutaneous fistula with a fasciocutaneous island flap pedicle on the superficial temporalis artery. Plast Reconstr Surg. 2000;106(7):1573–6.
13. Nayak VK, et al. Pedicled temporoparietal fascial flap reconstruction of select intraoral defects. Laryngoscope. 2004;114(9):1545–8.
14. Upton J, et al. The use of prefabricated fascial flaps for lining of the oral and nasal cavities. Plast Reconstr Surg. 1994;94:573.
15. Liu Y, et al. Reconstruction of facial defects using prefabricated expanded flaps carried by temporoparietal fascia flaps. Plast Reconstr Surg. 2009;123(2):556–61.
16. Kim JC, et al. Heir-bearing temporoparietal fascial flap reconstruction of upper lip and scalp defects. Arch Facial Plast Surg. 2001;3(3):107.
17. Navarro-Ceballos R, et al. Clinical applications of temporoparietal hair-bearing flaps for male pattern baldness and mustache formation. Aesthet Plast Surg. 1991;15(4):343–8.
18. Collar RM, et al. The versatility of the temporoparietal fascial flap in head and neck reconstruction. J Plast Reconstr Aesthet Surg. 2012;65:141–8.
19. Mathes SJ. Regional flaps: anatomy and basic techniques Head and Neck section. In: Reconstructive surgery principles, anatomy, technique, vol. 1. New York, NY: Churchill Livingstone; 1997. p. 367–85.

5 Radial Forearm Flap

R. Pellini, M. Ghirelli, F. Ferreli, B. Pichi,
G. Mercante, and G. Molteni

5.1 Anatomy

5.1.1 Artery

After passing underneath the biceps aponeurosis, the brachial artery divides into radial and ulnar arteries, at about one cm below the elbow ligament. The radial artery is located in the lateral intermuscular septum which separates the flexor and the extensor compartments of the forearm. Its superior half runs deep between the brachioradialis muscle and the rotundum pronator muscle, while its lower half runs between the tendons of the brachioradialis and the flexor radial carpalis. The radial pulse is palpable in the wrist, medial to the tip of the styloid process of the radius, and the artery is covered only by band and skin. The deep palmar arch is formed by the radial artery joining with the deep branch of the ulnar artery between the first and second metacarpal bone. Along its course, the radial artery rises up to 9–17 septocutaneous branches to supply the overlying fascia and skin. All of these ramifications, with an average diameter of 0.5 mm, form a rich network of vascularization in the subcutaneous layers, along with the fasciocutaneous ramifications of the ulnar, brachial, and interosseous arteries. Distal fasciocutaneous branches of radial artery can adequately perfuse all the skin of the forearm [1].

The periosteal blood supply to the distal radius relies on branches of the radial artery to the deep flexor pollicis longus and pronator quadratus muscles; perforators pass also through the lateral intermuscular septum from the radial artery to the periosteum. These perforators permit to harvest an osteocutaneous radial forearm flap including the distal anterolateral face of the radius.

5.1.2 Venous System

The radial forearm free flap (RFFF) has two venous drainage systems: a deep one, composed of two venae comitantes that accompany the radial artery and a superficial system, mainly

R. Pellini (✉) · F. Ferreli · B. Pichi
Department of Otolaryngology-Head and Neck Surgery, IRCCS “Regina Elena” National Cancer Institute, Rome, Italy
e-mail: raul.pellini@ifo.gov.it

M. Ghirelli
Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital of Modena, Modena, Italy

G. Mercante
Otorhinolaryngology Unit, Humanitas Clinical and Research Center-IRCCS, Humanitas University, Rozzano, Italy

G. Molteni
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

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composed of the cephalic vein laterally and the basilic vein medially.

The cephalic vein rises from the dorsal venous network, around the lateral margin of the distal forearm. It is a large, thick-walled vein that runs in a constant location deep to the subcutaneous fat plane. At the level of the elbow, the cephalic vein runs up to the anterolateral side of the arm, superficially at the groove between the brachioradialis muscle and biceps muscle.

The basilic vein runs deep into the fat plane along the medial side of the forearm.

A wide variety of venous connections can be encountered in the volar face of the forearm. The median cubital vein of the elbow joins the basilic and the cephalic vein in the proximal forearm. A short vein, the perforating cubitalis vein, connects the deep and superficial systems at the level of the antecubital fossa. These connections permit, in selected cases, to drain both superficial and deep venous system with a single anostomosis.

Moreover, a series of smaller veins form a sort of subcutaneous network.

Both superficial and deep systems are similarly able to drain the blood from the skin of the forearm. The multiple connections between the venae comitantes and the superficial veins form the basis for the use of either of these two systems to drain the flap.

5.1.3 Nerves

The cutaneous innervation of the forearm originates from the lateral and medial antebrachial cutaneous nerves. The lateral cutaneous antebrachial nerve (LCAN) is an extension of the muscle-cutaneous nerve that supplies the flexors muscle of the upper arm. After piercing the deep fascia of the cubital fossa, it runs deep under the cephalic vein to descend along the radial forearm face down to the wrist. With its anterior branch, it innervates the skin of the lateral half of the anterior surface of the forearm. The posterior branch supplies the sensation to the posterolateral forearm.

The medial antebrachial cutaneous nerve crosses the deep fascia in the medial part of the mid-upper arm. It divides into an anterior and a posterior branch. The anterior branch descends anteriorly to the basilic vein and innervates the skin of the anteromedial aspect of the forearm. The posterior branch lies anteriorly to the epitroclea of the humerus and innervates the skin of the posteromedial surface of the forearm.

The radial nerve has both motor and sensory components. In the forearm, it divides into a deep motor branch and a superficial sensory branch.

The deep branch of the radial nerve winds around the radius and comes to lie on the posterior interosseous membrane.

The superficial branch of the radial nerve, in its first tract, courses in the forearm, deep to the brachioradialis, and then passes laterally to the brachioradialis tendon where it becomes superficial, supplying sensation trough the dorsal digital nerves to the dorsum of the hand, thumb, index and middle fingers (Fig. 5.1).

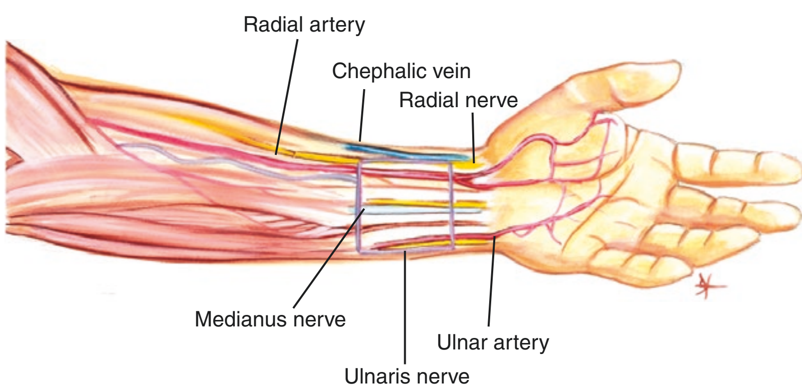

Fig. 5.1 Vascular and nervous anatomy of the flap

5.2 Analytical Factors and Technical Considerations

5.2.1 Venous Drainage: Superficial and Deep Vein System

Since the initial description of RFFF by Song R. in 1982, the superficial venous system was considered as the primary venous drainage of this flap [2]. The superficial venous systems are preferred by most of the surgeons for the larger diameter and thicker wall of the vessels, and a consequent easier anastomosis. Moreover, the independent and relative distant course of the cephalic vein and the radial artery, allows a simpler placement and maneuverability of both vein and artery, one to each other, in the receiving site.

It is argued which of the venous systems is the dominant one, whether the superficial or the deep one. The Ichinose et al. [3] hemodynamic study demonstrated that, at an early stage after flap elevation, the comitantes veins have twice the volume of drainage per unit time compared with the cephalic vein, and in 60% of cases, there is no obvious communication between the deep and superficial venous system.

Futran et al. [4] suggested that single venous anastomosis of the subcutaneous system provided adequate drainage of the flap reducing the operative time. The bigger concern of the supporters of the single superficial venous anastomosis is the inadequacy of the caliber of the deep veins. To overcome this limit Gottlieb et al. proposed the dissection of the pedicle up to the antecubital fossa near the confluence of the two venae comitantes [5]. In any case, the communication between the two system is absent in 40% of cases; moreover, the time of the dissection and morbidity to donor site increases, and a pedicle with an unnecessary length tends to be prone to kinking. On the other hand, the anastomosis of both drainage systems seem to reduce the venous pressure, creating a low-flow state, thus increasing the risk of venous thrombosis. Some authors suggested that the comitantes veins and the cephalic vein should be anastomosed independently on two distinct venous systems (internal and external jugular) assuring two separate and parallel drainage systems.

It is easy to note that still debate exists about which venous system prefer and whether one or two vein anastomosis give better results, probably because both the alternatives provide reliable and reproducible outcomes.

5.2.2 Sensate Flap

A sensate flap can be harvested using the LCAN. It can be anastomized in the neck with the proximal stump of the lingual nerve or more rarely with a branch of the cervical plexus. LCAN and its branches determine the most of the sensitive innervation of the RFFF, but also the medial cutaneous antebrachial nerve and the branches of the superficial radial nerve may innervate clinically relevant portions of the flap [6]. Reinnervation seems to favour sensory recovery providing larger, better arranged and more numerous nerve fibers compared to not-sensate flap [7]. Despite this, evidence about short and long term better functional outcomes with sensate flap is lacking, considering also the complexity and quantity of variables that affect recovery after reconstructive surgery [8]. On the other hand, section of the LCAN will invariably results in skin sensory deficits.

5.3 Flap Harvesting

5.3.1 Preoperative Management

At the admission, the patient and hospital personnel must be warned to avoid the violation of the nondominant forearm that must be shaved.

Although exceedingly rare, the occurrence of acute hand vascular insufficiency when harvesting a radial forearm free flap is always a possibility (two cases described in literature) and must be kept in mind.

The Allen test is the most important preoperative evaluation to assess the adequacy of the perfusion of the hand (especially the index and the thumb) through the residual ulnar artery, after forearm flap harvesting. Simultaneous digital compression of the ulnar and radial arteries is applied for few seconds by the examiner while the patient is invited to alternately open and close the hand. This pumping action causes mechanical exsanguination with the hand that becomes pale. The hand is then opened before releasing the compression on the ulnar artery. Reperfusion is evident trough a blush of the hand within 15–20 s. If a delay is noted, it can be concluded that there is not a good crossflow from the ulnar artery trough the palmar arch, representing, contraindication for proceeding with a radial forearm flap. Controlateral forearm vascular circulation should be explored.

There are no substantial differences in flaps harvested from the left or right side, so it is widespread practice to choose the donor site from the nondominant upper limb, although it is preferable to have the operating arm on the contralateral side to the resection to create more space for two surgical teams to work simultaneously. Previous intravenous lines positioning must be avoided on the side of the flap harvesting, but venepuncture itself is not an absolute contraindication. Previous surgery, scars, injury, fractures, and burns may contraindicate the use of a specific arm. Moreover, the patient's preference is taken into account.

The patient must be counseled about the possibility of donor site sequelae and, in particular, poor cosmetic results, use of a skin graft for closure and temporary or permanent variable sensory loss of the posterolateral portion of the hand.

5.3.2 Flap Design

The radial artery (Fig. 5.2) runs under a virtual line that joins the central point of the antecubital fossa and the tubercle of the scaphoid and, in the most of cases, it can be identified by palpation at the wrist, between the brachioradialis and the flexor carpi radialis tendon and marked on the skin for about 10 cm length starting from the distal border of the flap. The lateral intermuscular septum incorporates the radial artery and the venae comitantes. After inflating the tourniquet, the cephalic vein system is identified and marked on the volar and lateral aspect of the arm

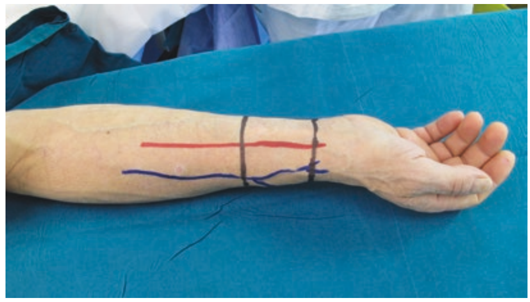

Fig. 5.2 Right arm: identification and drawing of the radial artery, cephalic vein and flap design

(Fig. 5.2). In fat arms, the cephalic vein may be not visible; in this case the probable course is marked based on anatomical knowledge. The size and shape of the flap are determined and marked on the forearm, often with a template from the estimated surgical defect. The axis of the flap should be centered over the course of the radial artery. The ulnar margin of the flap is outlined over the flexor carpi ulnaris muscle while the lateral has to be drawn beyond the radial artery, comprehending the cephalic vein. The flap can be extended ulnarward to the less hair bearing part of the forearm, as desired, while the dorsal aspect of the arm should be spare for aesthetic reasons. Proximal margin depends on the flap size needed.

5.3.3 Patient Positioning

The arm is placed 70° with respect to the patient's body on a self-stained board. Care must be taken to minimize traction on nerves in the axilla and elbow region.

We advise the use of the tourniquet to obtain a surgical field without bleeding during the dissection. Orthopaedic cotton bandage proximally wraps the arm to avoid the prolonged contact with the inflated tourniquet. Without proper protection, the underlying soft tissue is prone to damage caused by wrinkling, pinching, or shearing.

The cuff is secured around the limb proximal to the operative site. Pressure is exerted on the circumference of the arm; when sufficient pressure is obtained, vessels and arteries beneath the cuff become temporarily occluded, preventing blood flow past the cuff. While the cuff is inflated, the tourniquet system automatically monitors and maintains the pressure chosen by the user (approximately 250 mmHg). Cuff pressure and inflation time are displayed, and an audiovisual alarm alert informs the user to alarm conditions, such as a cuff leak.

Pneumatic surgical tourniquet prevents blood flow to the arm and enables the surgeon to work in a bloodless operative field (Fig. 5.3).

Before the tourniquet inflation, moderate exsanguination of the limb is also recommended using an Esmarch bandage (a narrow elastic bandage 5–10 cm wide) before inflating the tourniquet to stop the arterial flow (Fig. 5.4).

The acceptable range of tolerance to ischemia of the arm remains controversial. Tolerance of composite tissue is dependent on the quantity of contained skeletal muscle. VanderWilde et al. reported a successful hand replantation after 54 hours of cold ischemia [9].

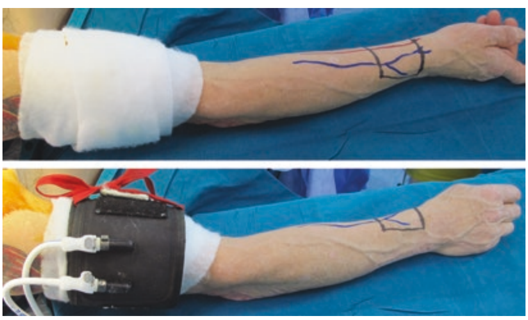

Fig. 5.3 Pneumatic surgical tourniquet prevents blood flow to the arm and enables the surgeon to work in a bloodless operative field

Fig. 5.4 Esmarch bandage is used to expel venous blood from the arm (exsanguinate) elevating the limb as the elastic pressure is applied

5.4 Surgical Steps

5.4.1 Step 1

The procedure starts with the elevation of the superior skin flap: after the flap has been marked, a median skin incision is prolonged from the upper border of the flap to the antecubital fossa. A superior (radial) skin and subcutaneous flap is harvested, exposing the course of the superficial vein system. Careful dissection of the cephalic vein that runs over the brachioradialis musle, ligating its collateral branches, permits to harvest a thicker skin flap, reducing the risk of necrosis (Fig. 5.5).

5.4.2 Step 2

Elevation of the RFFF starts trough the incision of the skin at the radial border through the subcutaneous fatty tissue until the forearm fascia is reached. The fascia is incised and elevated from lateral to medial. A collateral branch of the cephalic vein is recognized: it is transected and the proximal stump of the vein is sutured to the subfascial plane of the flap in order to avoid a vein detachement due to traction (Fig. 5.6).

5.4.3 Step 3

The distal margin of the flap is incised. The fascial plane is identified above the cephalic vein and its branches. At the distal aspect of the flap

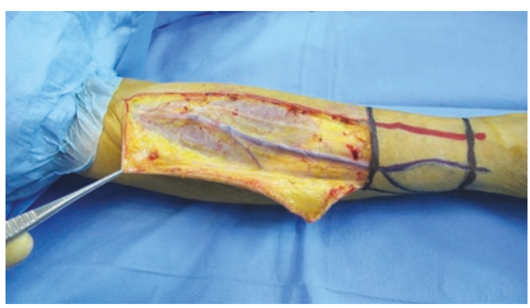

Fig. 5.5 Harvesting of the superior skin flap with exposition of the course of the cephalic vein

the vein is completely isolated and transected (Figs. 5.6 and 5.7). Radial dissection is carried out in a subfascial plane, elevating the flap off from the tendons of the muscle in the flexor compartment. The superficial branch of the radial nerve is (Fig. 5.7) usually identified over the tendon of brachioradialis muscle. There are usually two main distal branches: although the distal branching pattern is highly variable, the major branches are always encountered in the wrist while elevating the radial forearm flap. This nerve and all its branches can be routinely preserved to maintain sensation to the hand. By careful dissection, a lateral cutaneous antebrachial nerve becomes visible. The LCAN is identified usually in the central to slightly radial aspect of the flap. This sensory nerve usually runs in close proximity to the cephalic vein in the upper forearm before ramifying in the distal forearm and continuing onto the hand in the region of the thenar eminence.

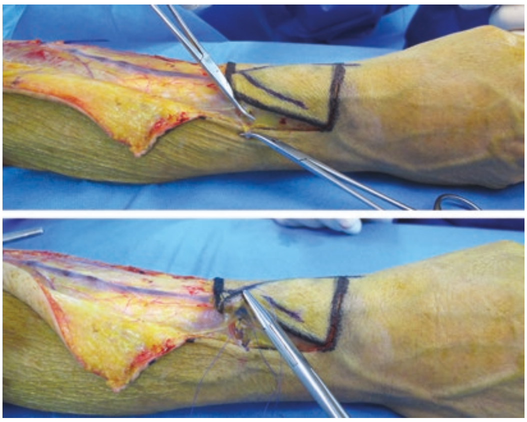

Fig. 5.6 Identification (left) and ligation (right) of a collateral branch of the cephalic vein

5.4.4 Step 4

The intermuscular septum containing the radial artery and venae comitantes is identified and separated from the brachioradialis muscle. Vessels are sectioned, ligated, and carefully elevated together with the flap. The radial artery is isolated distally, where it is only covered by fascia and skin and lies between the tendon of the brachioradialis and the flexor carpi radialis muscles (Fig. 5.8).

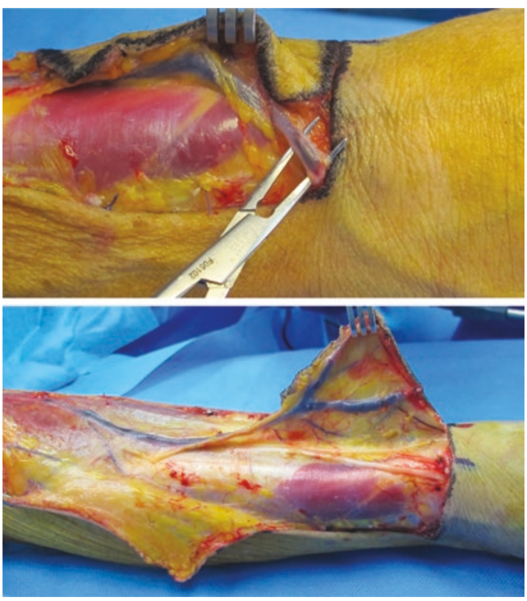

Fig. 5.7 Identification, section and ligation of the cephalic vein. Subfascial dissection of the flap, preserving the superficial branch of the radial nerve

Fig. 5.8 Identification, section and ligation of the radial artery

5.4.5 Step 5

The radial artery is dissected distally to proximally by transecting and cauterizing the deeper branches that supply the muscles of the forearm and the radius. It's important to maintain the integrity of the paratenon when performing this dissection. Vessels, fascia and skin must be sutured, usually with few stitches with Vicryl 3–0, to avoid superficial devascularization. The tendon of the flexor muscles and palmaris longus (not present in our dissection and reported to be absent in 20% of patients) are exposed (Fig. 5.9).

5.4.6 Step 6

In the distal third of the forearm, where the radial artery is not covered by muscle bellies, the septum contains the highest number of cutaneous perforators. In this area numerous small branches directed to the deep muscle and to the radial bone have to be identified and cauterized or clipped (Fig. 5.10).

Exposure of the proximal radial artery and the venae comitantes is achieved by separating the brachioradialis from the flexor carpi radialis (Fig. 5.11).

5.4.7 Step 7

The dissection of the medial border of the brachiradialis muscle and its lateral retraction allows the exposure of the pedicle in its entire length (Fig. 5.12).

Some perforator branches from the radial artery are identified in the middle and proximal third of the forearm and clipped (Fig. 5.13). It is advisable to cauterize or tight the vessels as far as possible from the pedicle to avoid its damage.

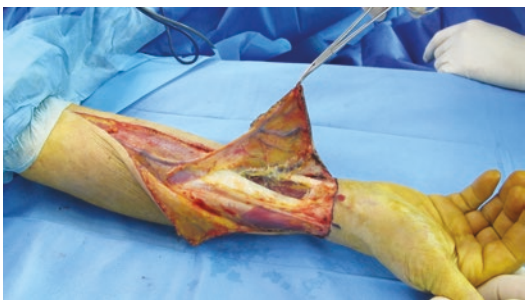

Fig. 5.9 Subfascial dissection of the flap. Intermuscular septum with radial artery and concomitantes veins and tendon of brachiradial (lateral) and radial flexor palmaris (medial) are exposed

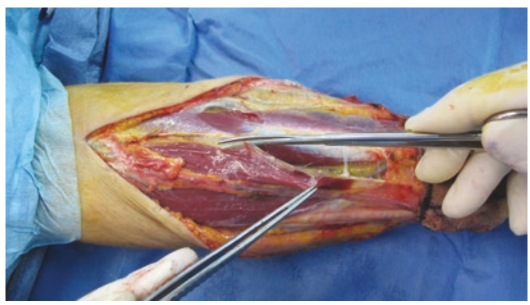

Fig. 5.11 Exposure of the radial artery up to the antecubital fossa

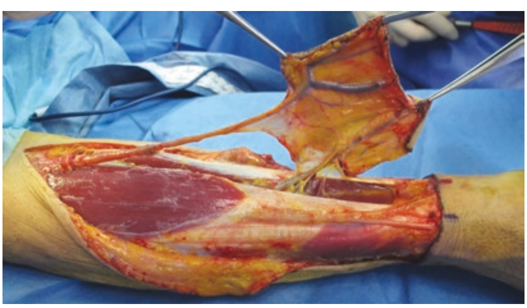

Fig. 5.10 Elevation of the flap and identification of numerous deep perforating vessels

Fig. 5.12 Retraction of the brachioradialis muscle to expose the vascular pedicle

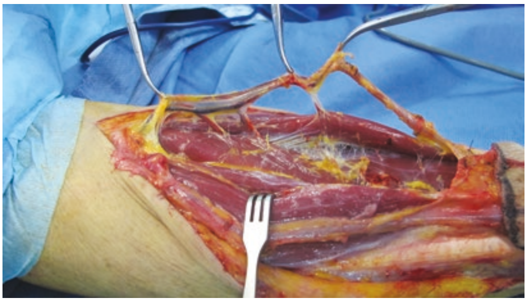

Fig. 5.13 Identification of the proximal perforating vessels of the radial artery

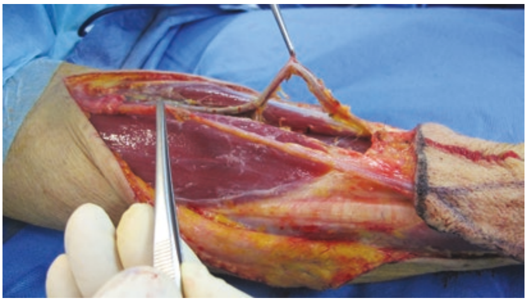

Fig. 5.14 Vascular pedicles are freed for their whole length

5.4.8 Step 8

The vascular pedicled is traced proximally until the desired length is reached, depending on the subsequent kind of reconstruction. It is possible to harvest the pedicle up to the confluence with the brachial artery. The length of the pedicle has to be long enough to reach the donor vessels, but an excessive long pedicle could generate a kneeling or a kinking, thus increasing the risk of thrombosis (Fig. 5.14).

5.4.9 Step 9

At the same way, the cephalic vein is exposed up to the level of the antecubital fossa, where a venous anastomosis between superficial and deep circulation can be usually identified. Harvesting the vein proximal to this point allows the surgeon to maintain both superficial and deep venous drainage. Otherwise, it is possible to harvest separately the cephalic vein and venae comitantes (Fig. 5.15). At this point, the tourniquet is deflated, and accurate hemostasis is obtained with bipolar forceps or hemoclips if necessary. Accurate hemostasis is of paramount importance to prevent bleeding after flap inset and hematoma formation. Section of the pedicle is not performed until the recipient vessels are ready for anastomosis (Fig. 5.15).

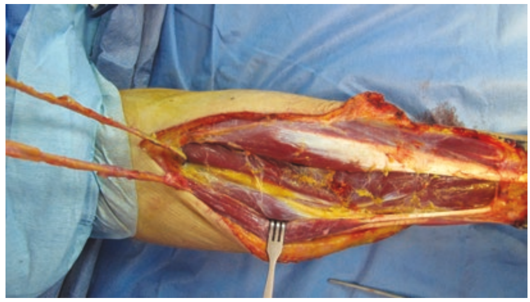

Fig. 5.15 Cephalic vein is followed up to the antecubital fossa. Note the interindependent cours of the arterial pedicle and the superficial vein pedicle

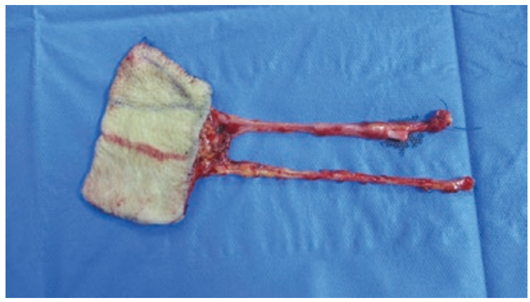

Fig. 5.16 The radial forearm flap with the radial artery, the comitantes veins, and the cephalic vein

5.5 Final Aspect of the Flap

Once the demolitive procedure has been completed, vascular pedicles are carefully sectioned and the flap is detached (Fig. 5.16). The vessels of the flap may be divided at any point along their course to reach the recipient vessels, avoiding kinking.

5.6 Donor Site Closure

The radial forearm flap is a highly reliable method of reconstruction, but there are some donor site problems that may be encountered (total or partial loss of skin, necrosis, seroma, infection, wound dehiscence). Many skin closure method has been proposed, but as of today, the topic is somewhat controversial.

Many surgeons prefer to harvest a split-thickness skin graft from distant sites (thigh, groin), but adjuntive morbidities including pain, infection, or hypertrophic scar formation have to be considered. Other authors report the use of a suprafascial dissection technique with primary closure of the forearm and split-thickness skin graft.

Some recent studies demonstrate that suprafascial harvest of the radial free flap decreases the incidence of postoperative tendon exposure at the donor site, resulting in a reduced burden of postoperative wound management [10, 11].

A few authors have suggested alternative closure including tissue expanders, full-thickness skin grafts, and transposition flaps to improve outcomes. An other alternative the ulnar-based transposition flap as an alternative closure method for small donor defects.

The authors generally perform the skin closure after flap harvesting with a full-thickness skin graft previously harvested. In this case, at the beginning of the procedure, a full-thickness skin graft can be elevated on the volar face of the forearm. The skin graft is isosceles triangle shaped, with the height twice the radial forearm flap length, in the direction of the forearm axis. The base of the triangle is the same as the width of the proximal side of the forearm flap. The skin graft is then preserved in physiological solution until the flap has been detached. The cutaneous margins of the defect must be dissected to favor the subsequent suture of the proximal portion of the donor site. The suction drainage should be placed in the most cranial portion of the surgical field to avoid the skin graft failure (Fig. 5.17).

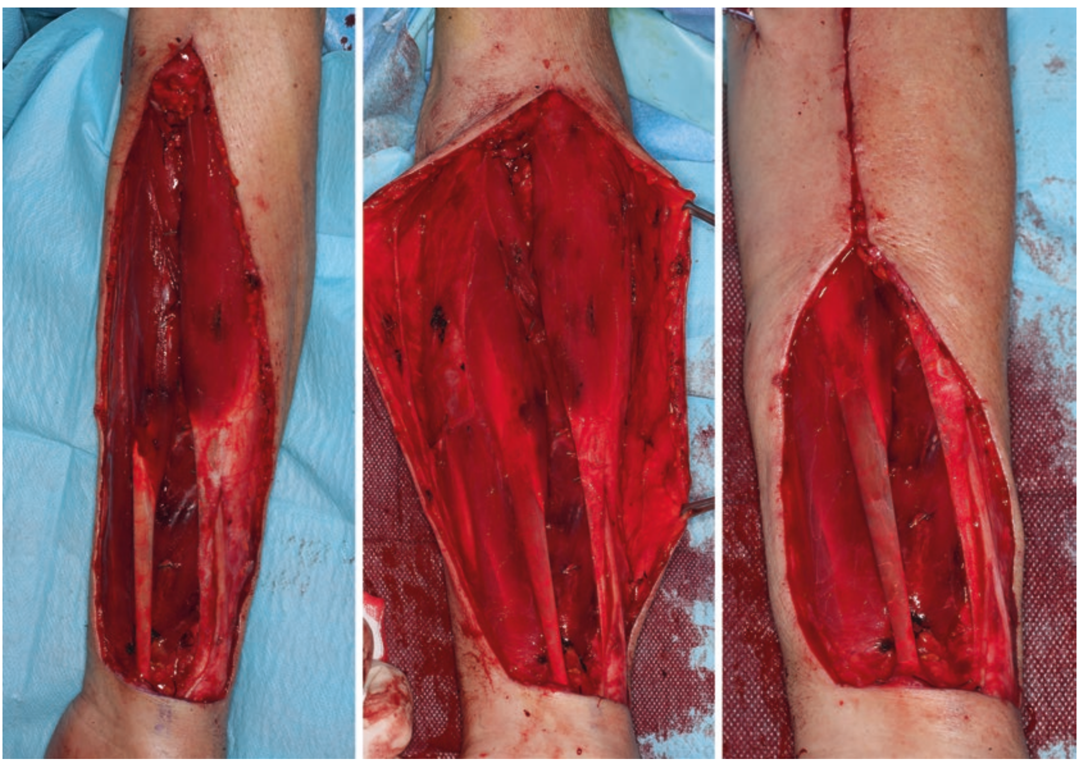

Fig. 5.17 Final aspect of the the forearm with the residual surgical defect

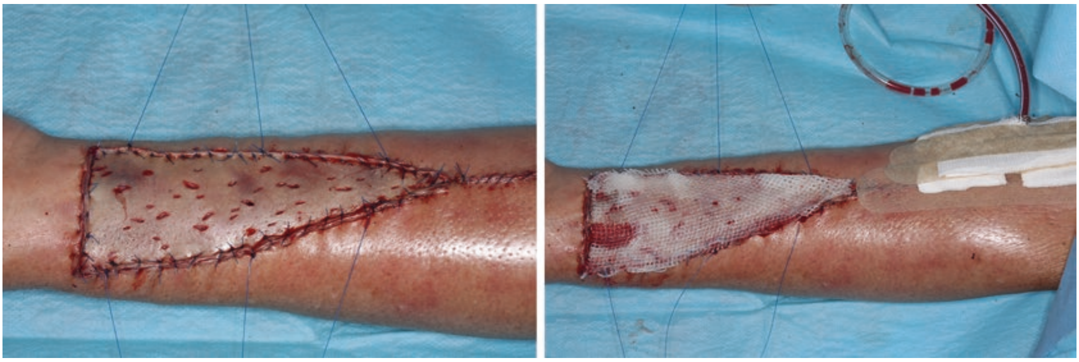

Fig. 5.18 Placement of the skin graft. A compressive-dressing is used to cover and facilitate healing

The skin graft is positioned with the base on the distal side of the residual defect, and both sides are progressively sutured to the residual skin graft. The proximal portion of the forearm is close with V-Y advancement technique. Multiple slits in the graft are made to prevent fluid collection and to allow the graft to be stretched to cover a large area. After the suture is completed, wet gauzes (with paraffin) and compressive dressing (tie-over) are made and take in place for 7–10 days (Fig. 5.18).

Most authors have concluded that, without subjective complaints and patient's noticing interference with activities of daily living, the morbidities associated with RFFF are acceptable and well tolerated, even after long-term follow-up.

5.7 Composite Flaps

5.7.1 Tendon-Fasciocoutaneous Radial Forearm Flap

The palmaris longus muscle and tendon can be seen by flexing the wrist and touching the pads of the first and fifth finger. If present, it will be visible in the midline of the anterior wrist. It is absent in up to 15% of individuals. It is a weak flexor and provides no substantial flexing force, so tendon removing does not cause significant loss of hand function.

In the head and neck, the tendon is mainly used in lower lip reconstruction or static facial suspension.

After preoperative identification, the flap is draped over the tendon. The flap is elevated in a standard fashion, and the palmaris longus tendon is incorporated in the flap by incising the deep fascia medial to the tendon, down to the deeper muscle. The proximal and the distal ends of the tendon are transected 2 cm from the flap.

When the palmaris longus tendon is absent, the flexor carpi radialis tendon can be used as alternative, with limited functional impairment.

5.7.2 Osteo-Fasciocutaneous Radial Forearm Flap

It is possible to harvest a forearm flap with a portion of the radius with the advantage to have a composite flap with a long pedicle and thin and pliable skin. Unfortunately, the bone is inadequate for bone-integrated implants and reconstruction of areas subject to great force and torque, as in case of mandible reconstruction after segmental resection. Moreover, the limited bone length (about 12 cm) that can be harvested, the risk of forearm fracture, and the long period of postoperative forearm rehabilitation, entail the use of the flap only for selected cases of midface and periorbital reconstruction.

Up to 40% of the circumference of a midlateral portion of the radius can be harvested. The available bone lies between the insertion of the pronator teres muscle and the insertion of the brachioradialis muscle laterally at the base of the radial styloid. During the flap harvesting, the lateral dissection has to be conduit deep to the brachioradialis tendon and muscle that have to be widely retracted, to make the dissection quite lateral to the radial artery avoiding the injury to the perforator that supplies the bone. On the opposite medial side, the dissection requires the incision of the deep fascia over the pronator quadratus, flexor pollicis longus, and flexor digitorum superficialis muscles that are exposed after medial retraction of the flexor carpi radialis muscle and lateral gentle retraction of the flap with the vascular pedicle not yet distally divided. The partial release and retraction of the flexor digitorum superficialis muscle permit the exposure of the flexor pollicis longus that is longitudinally cut exposing the periosteum of the medial surface of the radius. After the exposure of the bone, the radial artery and the comitantes vein can be distally legated and resected, anchoring the proximal stump to the fascial portion of the flap. With a high-speed oscillating saw in the medial-lateral direction, the radius is cut along its length, taking care to leave intact about 60% of the circumference of the bone and to perform the proximal and distal osteotomies with an angle of about 45° to avoid the creation of stress point. After the bone resection is done, the osteo-fasciocutaneous flap is completely elevated, and prophylactically plate fixation of the remaining radius is done with appropriate thickness plate fixed out of the bone gap with 2/3 bicortical screw proximally and distally. The fixed plate must be completely covered by muscles and skin mobilized over the lateral forearm, and a skin graft covers the soft tissue. For three weeks after surgery, the forearm is immobilized by a volar splint.

References

1. Henker DD, et al. Perforator anatomy of the radial forearm free flaps versus the ulnar forearm free flap for head and neck reconstruction. Int J Oral Maxillofac Surg. 2016;45(8):955–9.
2. Song R, Gao Y, Song Y, Yu Y, Song Y. The forearm flap. Clin Plast Surg. 1982;9(1):21–6.
3. Ichinose A, Tahara S, Terashi H, Yokoo S, Nakahara M, Hashikawa K, Kenmoku K. Importance of the deep vein in the drainage of a radial forearm flap: a haemodynamic study. Scand J Plast Reconstr Surg Hand Surg. 2003;37(3):145–9.
4. Futran ND, Stack BC Jr. Single versus dual venous drainage of the radial forearm free flap. Am J Otolaryngol. 1996;17(2):112–7.
5. Gottlieb LJ, Tachmes L, Pielet RW. Improved venous drainage of the radial artery forearm free flap: use of the profundus cubitalis vein. J Reconstr Microsurg. 1993;9(4):281–4; discussion 284–5.
6. Boutros S, et al. Neural anatomy of the radial forearm flap. Ann Plast Surg. 2000;44(4):375–80.
7. Kim JH, Rho YS, Ahn HY, Chung CH. Comparison of sensory recovery and morphologic change between sensate and nonsensate flaps in oral cavity and oropharyngeal reconstruction. Head Neck. 2008;30(8):1099–104.
8. Namin AW, Varvares MA. Functional outcomes of sensate versus insensate free flap reconstruction in oral and oropharyngeal reconstruction: a systematic review. Head Neck. 2016;38(11):1717–21.
9. VanderWilde RS, Wood MB, Zu ZG. Hand replantation after 54 hours of cold ischemia: a case report. J Hand Surg Am. 1992;17(2):217–20.
10. Shonka DC, et al. Suprafascial harvest of the radial forearm flap decreases the risk of postoperative tendon exposure. Ann Otol Rhinol Laryngol. 2017;126(3):224–8.
11. Schwarzer C, et al. Donor site morbidity and flap perfusion of subfascial and suprafascial radial forearm flaps: a randomized prospective clinical comparison trial. J Craniomaxillofac Surg. 2016;44(9):1299–304.

6 Rectus Abdominis Free Flap

G. Molteni, M. Ghirelli, C. Plotegher, C. Piazza, and R. Pellini

6.1 Anatomy

6.1.1 Muscles

The main muscular structures involved in the preparation of this flap are the rectus muscles of the abdomen and the fascial envelopes that form the abdominal wall and contain the muscles themselves.

The rectus muscles are even, paramedian with a vertical orientation.

G. Molteni (✉)
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

M. Ghirelli
Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital of Modena, Modena, Italy

C. Plotegher
Maxillofacial Surgery and Dentistry, University Hospital of Verona Borgo Roma, Verona, Italy

C. Piazza
Department of Otorhinolaryngology, Maxillofacial, and Thyroid Surgery, Fondazione IRCCS, National Cancer Institute of Milan, University of Milan, Milan, Italy

R. Pellini
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

They originate from the cartilaginous parts of the sixth, seventh, and eighth ribs and the xiphoid process. They distally insert at the level of the pubic tubercle where, in most cases, they are covered by the pyramidalis muscle.

Each muscle has three connective horizontal bands, in the form of tendinous indentations, which separate both muscles into four segments.

The muscles are enveloped by the anterior and posterior rectus sheaths. The anterior one is formed by the union of the external oblique muscle fascia with the anterior part of the internal oblique muscle. The posterior sheath is formed by the posterior part of the internal oblique fascia and the transversalis muscle above the arcuate line (which is located at the level of the anterosuperior iliac spine). Below the arcuate line, the posterior rectus muscle sheath is represented by the transversalis fascia alone. This is its thinnest part and represents also a locus minoris resistentiae for abdominal herniation and postoperative incisional hernia. Fascias are joined on the midline forming the white line (linea alba), while the linea semilunaris represents its lateral limit.

6.1.2 Artery and Venous Systems

The rectus muscles and the abdominal skin are vascularized from two dominant pedicles: the deep inferior epigastric artery (DIEA) with its two venae comitantes, running along the posterior surface of

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the muscle within the rectus sheath, and the deep superior epigastric artery (DSEA). These two vascular networks can have up to four anastomotic branches, all at the periumbilical level.

The DIEA arises from the anteromedial aspect of the external iliac artery and runs superiorly in an extraperitoneal plane. Three or four centimeters below the arched line, the artery crosses the transversalis fascia and continues toward the lateral edge of the rectus abdominis muscle. DIEA runs upward while remaining in between the posterior surface of the rectus muscle and the posterior rectus sheath. Along the way, they give origin to a number of musculocutaneous perforators, especially at the level of the periumbilical region. DSEA develops directly from the internal mammary artery.

The main pedicle used is the DIEA since it is the dominant vascular supply and presents the larger artery.

Mean arterial caliber (DIEA) ranges from 1.5 to 2.5 mm, whereas mean venous caliber is between 2.0 and 3.0 mm. The two venae comitantes converge to form a larger vein that drains into the external iliac vein that can be harvested for a better venous drainage.

Pedicle length is approximately from 7 to 12 cm. The vessels enter the rectus muscle at its undersurface mostly at its middle (78%), seldom at its distal (17%), or proximal (5%) thirds [1].

6.1.3 Nerves

The rectus muscle is innervated by the segmental nerves, which provide motor innervation. These derive from the terminal branches of the lower six intercostal nerves and penetrate the posterior rectus sheath about 3 cm medial to the linea semilunaris. Lateral cutaneous nerves from the 7th to the 12th intercostal nerves also provide sensation to the skin territory overlying the rectus abdominis muscle.

6.2 Analytical Factors and Technical Considerations

According to the classification of Mathes and Nahai, rectus abdominis free flap has a type III perfusion. Free tissue transfer of this flap should be based on the DIEA pedicle. This type of flap can be prepared with various components: myofascial, myocutaneous, or chondro-myocutaneous.

It is essential to remember the position of the arcuate line located few centimeters below the umbilicus or at the level of the anterior superior iliac spines. Below this line, the internal oblique and transversus abdominis aponeuroses contribute only to the anterior rectus sheath.

Therefore, the arcuate line represents the lower limit of the posterior rectus sheath. This is an essential surgical landmark as the anterior rectus sheath should be excised only above the arcuate line; otherwise, the postsurgical abdominal wall will be weaker and prone to herniation.

6.3 Flap Harvesting

6.3.1 Preoperative Management

A history of previous abdominal surgery and the presence of incisional, inguinal, or crural hernias are of paramount importance during preoperative evaluation. Patients with advanced tumors may have placed a PEG for nutritional reasons. This does not contraindicate the harvesting of the flap but often forces its design.

Furthermore, it is essential to evaluate the thickness of fascio-cutaneous component of the flap in obese patients. As a matter of fact, flaps with an excessive adipose component are heavy and difficult to mold and may harbor postoperative liponecrosis phenomena if only one or two perforators are available [2].

The presence and course of DIEA are very constant, and therefore, it is not necessary to perform any preoperative radiological evaluation. However, it can be helpful to evaluate the precise position of the vascular pedicle by a preoperative Doppler (Fig. 6.1).

6.3.2 Patient Positioning

Flap harvesting is performed with the patient in the supine position. The abdomen is exposed from the xiphoid to the pubis. The operative field should be prepared including the lower ribs and

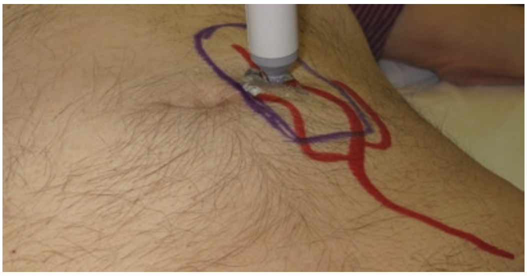


Fig. 6.1 Doppler identification of the vascular pedicle

the upper thigh of both sides as well as the pubic area.

6.3.3 Flap Design

Design of the skin paddle can have different orientations: transversal (TRAM), vertical (VRAM), and oblique. In design planning, a part of the paraumbilical area should be always included, because most of the dominant perforators are herein located.

The VRAM flap includes only the skin above the rectus muscle of one side, while the TRAM flap may include also the contralateral skin. When planning the TRAM flap, it is useful to remember that the skin overlying the rectus abdominis muscles is divided into four zones: zone 1, portion above one muscle; zone 2, above the contralateral muscle; zone 3, lateral to zone 1; and zone 4, the less vascularized one and is positioned externally and lateral to zone 2 [3].

The TRAM variant is often used for mammary reconstructions but can also be used in the head and neck area.

In the variant with the oblique course (*extended deep inferior epigastric flap*), the skin paddle starts from the paraumbilical region and can reach up to the apex of the scapula, with the associated muscle taken as a whole or just in part. If necessary, this flap may also include a portion of the vascularized rib [4].

The main landmarks are the linea alba (blue arrow) outlined on the midline from the pubis to the xiphoid, the iliac crest (black arrow), and the costal margin (green arrows). The linea semilunaris is positioned about 7–10 cm lateral to the linea alba, between the pubis and the anterior superior iliac spine (yellow arrow).

The vascular pedicle (DIEA) is located at the inferolateral edge of the rectus abdominis muscle. The arcuate line is located approximately at the height of the anterior superior iliac spines. The anterior rectus sheath should not be harvested below this level (Fig. 6.2).

VRAM is designed above a single rectus muscle. The central portion of the flap must be centered at the level of the periumbilical region and can be extended from the pubic region to the costal arch. Medial and lateral limits are represented by the linea alba and the linea semilunaris (Fig. 6.3).

TRAM can be designed in the supra- or sub-umbilical regions. The amount of skin that can be safely harvested reaches 40 cm in length and 15 cm in width. Such big dimensions in the head and neck district are seldom necessary. However,

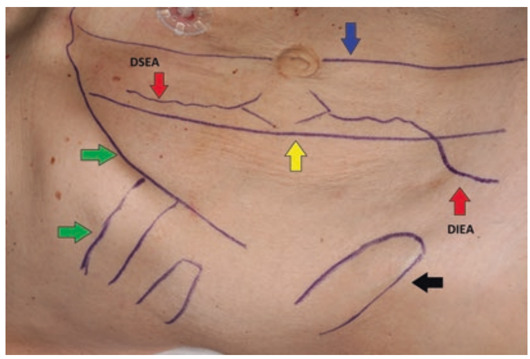


Fig. 6.2 Preoperative identification of anatomical landmarks: linea alba (blue arrow), iliac crest (black arrow), costal margin (green arrows), linea semilunaris (yellow arrow)

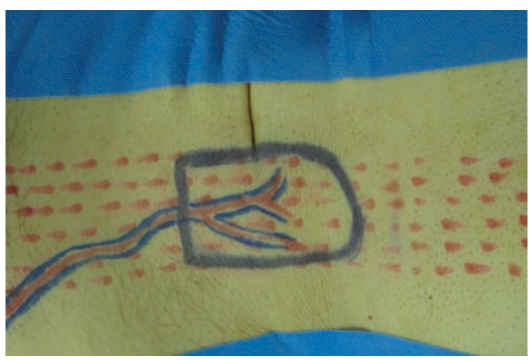


Fig. 6.3 VRAM: design of the flap

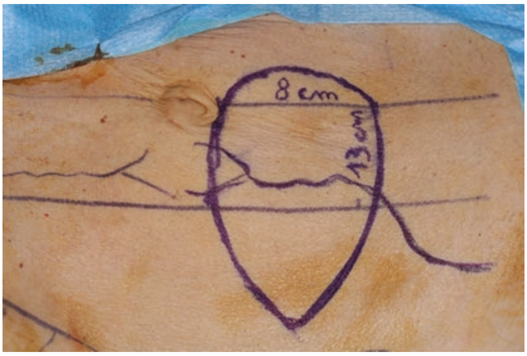


Fig. 6.4 TRAM: design of the flap

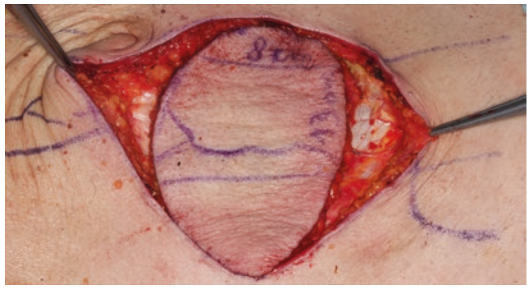


Fig. 6.5 Step 1: TRAM skin incision

Fig. 6.6 Step 1: VRAM skin incision

this type of flap allows a substantial skin withdrawal and a reasonably esthetical closure of the donor site (Fig. 6.4).

6.4 Surgical Steps

6.4.1 Step 1

Incision of the skin is performed along the entire edge of the skin paddle until it reaches the anterior rectus sheath (Fig. 6.5).

In the VRAM flap, the incision can be prolonged, along the paramedian line (black arrow) (Fig. 6.6).

Subsequently, the skin and subcutaneous tissue are dissected, exposing the anterior rectus sheath (Fig. 6.7).

6.4.2 Step 2

Incision of the anterior rectus sheath is carried out first cranially and then caudally until the muscle is exposed (Fig. 6.8), bearing in mind not to incise the rectus sheath below the arcuate line.

Upper and lower portions of the anterior sheath are incised. In VRAM flap, the vertical incision of the rectus fascia in a lateral position allows a direct suture facilitating the closure of the abdominal wall (Fig. 6.9). Every effort should be made to remove as less anterior rectus sheath as possible, undermining the subcutaneous plane, finding the perforators when they leave the fascia entering into the skin paddle, and removing just the small portion of fascia surrounding them. This sometimes allows removing a 3 × 3 cm piece of fascia, still vascularizing an 8 × 8 cm or more skin paddle.

6.4.3 Step 3

The muscolocutaneous perforators are identified laterally, above the anterior fascia (black arrow). After identification of the external oblique muscle and its aponeurosis at the linea semilunaris, the fascia is incised lateral to the perforators and linea semilunaris (Fig. 6.10).

It may be useful to place some sutures to fix the skin paddle and the subcutaneous tissue to the muscle, avoiding traction and sliding injuries to the musculocutaneous perforators (Fig. 6.11 and 6.12).

6.4.4 Step 4

The superior edge of the rectus muscle is horizontally incised with an electric or harmonic scalpel.

Before dissecting the muscle, it is essential to separate it from the posterior fascia with a blunt dissection. The muscle at the tendinous intersec-

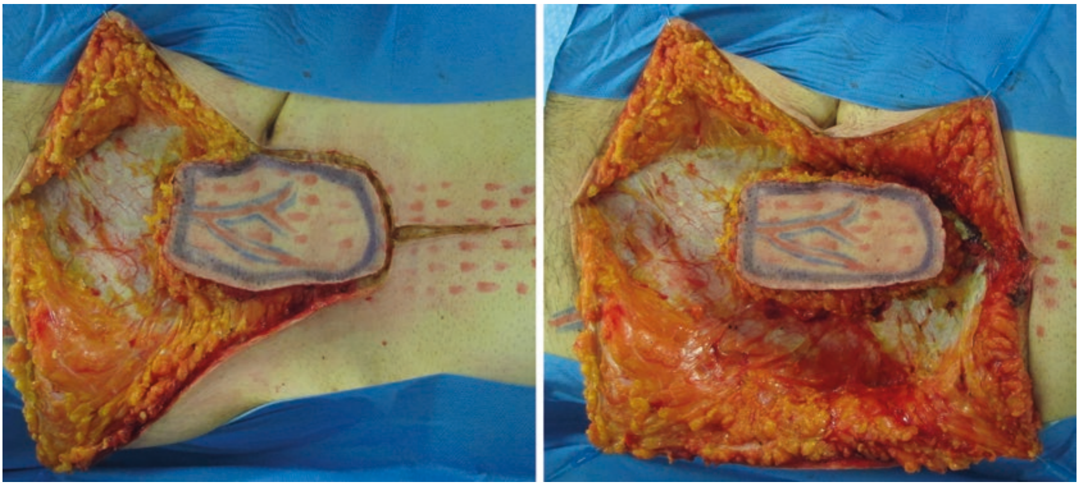


Fig. 6.7 Step 2: incision of anterior rectus sheath VRAM

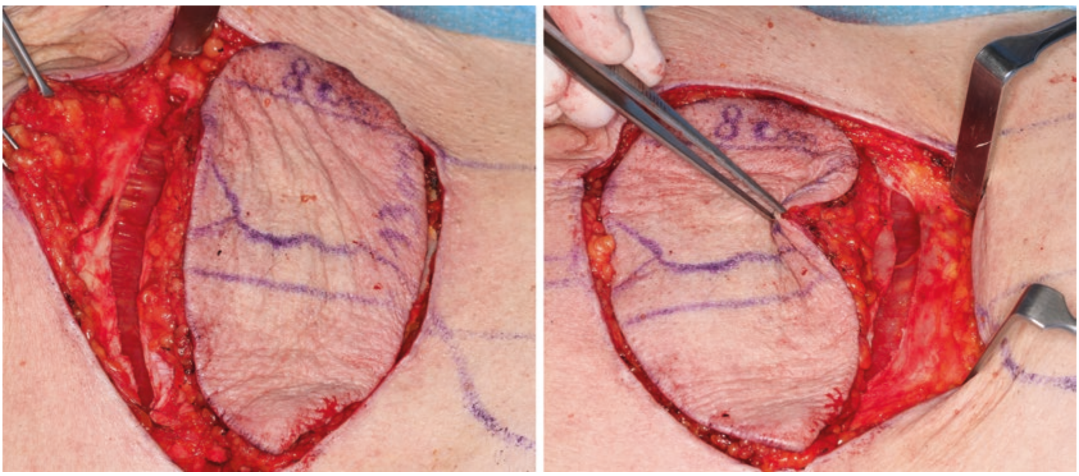


Fig. 6.8 Step 2: incision of anterior rectus sheath TRAM

Fig. 6.9 Step 2: lateral incision of the anterior fascia VRAM

tion can be divided, to obtain good hemostasis (Figs. 6.13 and 6.14).

The DSEA normally runs along the deep surface of the superior portion of the muscle or in its context. In any case, it can be easily identified (white arrow) and dissected (Fig. 6.15). Harmonic scalpel can be used to speed up this step. If an effective hemostasis cannot be achieved, hemostatic suture should be applied at the level of the cut edge of the flap.

6.4.5 Step 5

At this point, the flap is gently raised from its posterior sheath by blunt dissection, proceeding from

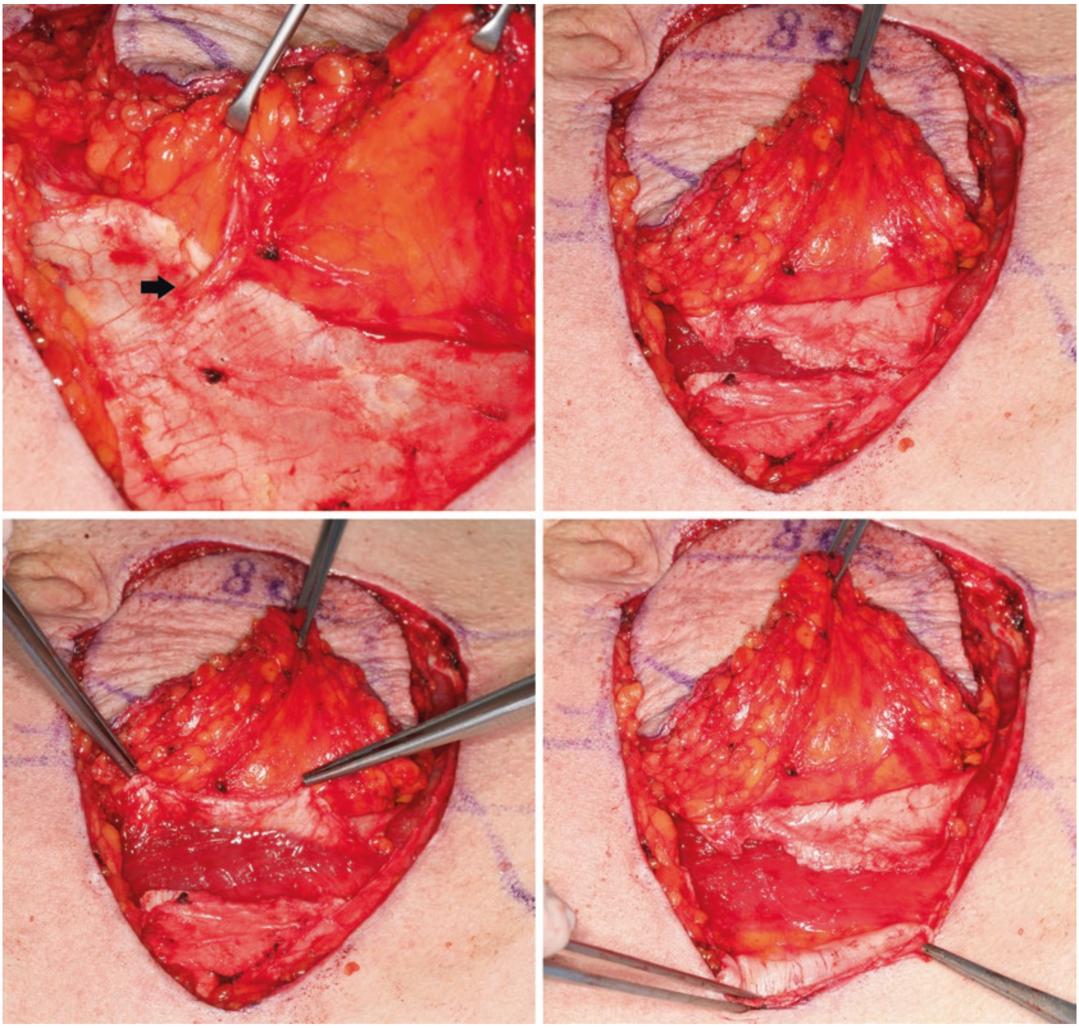


Fig. 6.10 Step 3: lateral incision of the anterior fascia TRAM

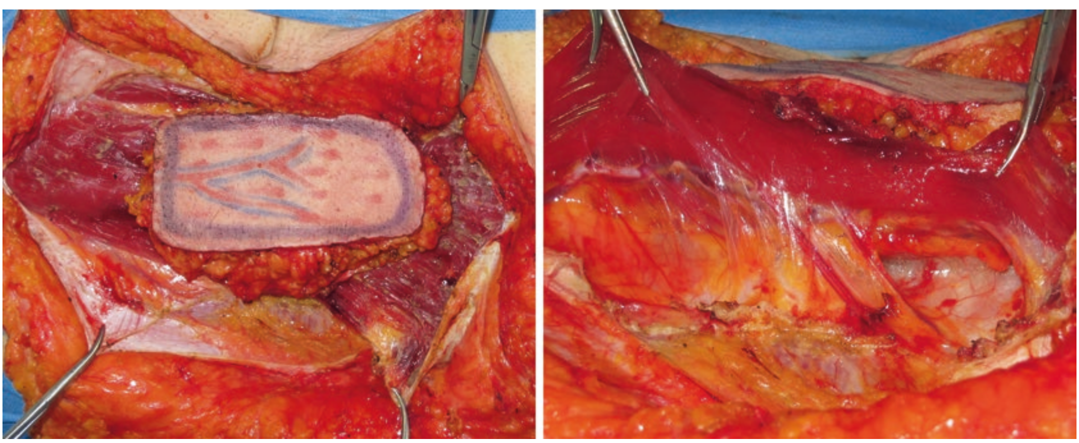


Fig. 6.11 Step 3: pedicle can be seen under the rectus muscle

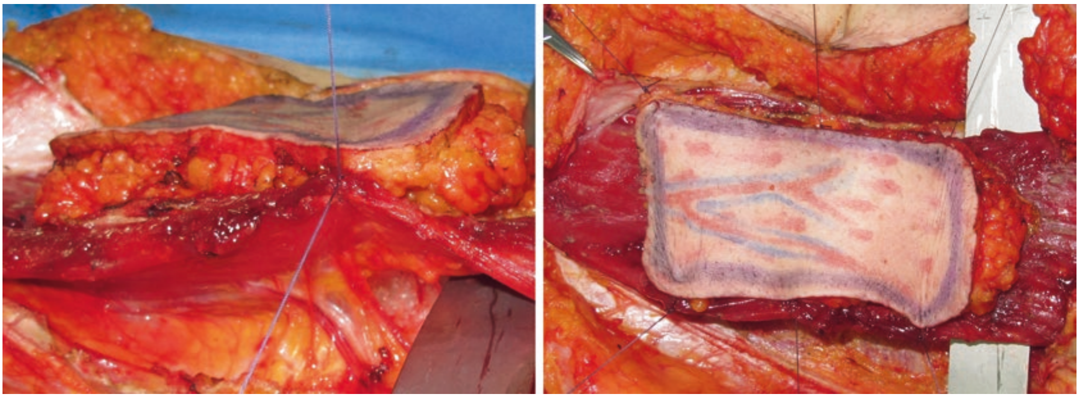


Fig. 6.12 Step 3: placing sutures to fix the skin paddle and the subcutaneous tissue to the muscle

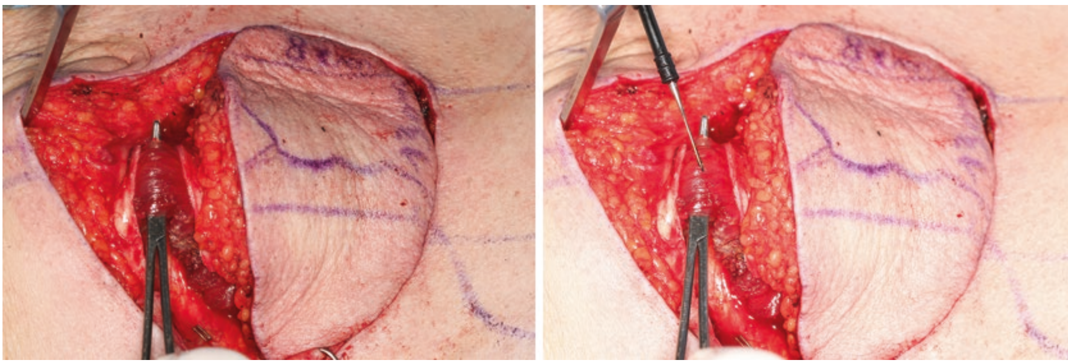


Fig. 6.13 Step 4: rectus muscle is horizontally incised with monopolar cautery

cephalad to caudal. It is imperative to preserve the integrity of the posterior rectus sheath (green arrow). Pedicle (white arrow) is visible on the undersurface of the muscle (Fig. 6.16). Segmental nerves from intercostal nerves are dissected (Fig. 6.17).

6.4.6 Step 6

In the TRAM variant, the anterior rectus sheath below linea arcuata is cut vertically, preserving it for subsequent direct closure (Fig. 6.18). This step in VRAM has been highlighted in Fig. 6.9, Step 2.

6.4.7 Step 7

The vascular pedicle is represented by the DIEA and its two venae comitantes lying in the undersurface of the rectus abdominis muscle (white arrow) (Fig. 6.19).

The pedicle is usually surrounded by adipose tissue (Fig. 6.20).

Once the vascular pedicle has been isolated from the adjacent soft tissues and protected, the lower portion of the rectus muscle can be transected. At this point, the flap can be detached. A pedicle length of 6–10 cm can be easily obtained by dissecting it until the external iliac artery (Fig. 6.21). In close proximity of the external iliac vein, usually 1–2 cm before the entry of the DIEA in such a large vessel, the two venae comitantes join together in one larger vein on which, especially in the case of a big skin paddle, anastomosis should be preferably done.

6.4.8 Step 8

Final appearance of the TRAM (Fig. 6.22) and VRAM flaps (Fig. 6.23).

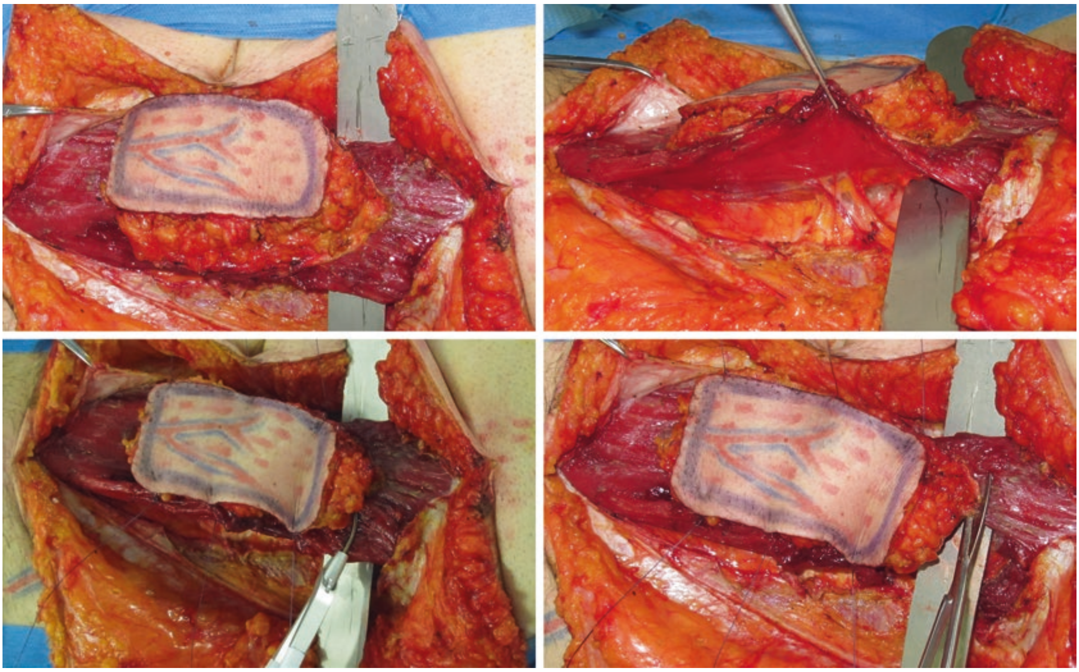


Fig. 6.14 Step 4: rectus muscle is horizontally incised with harmonic scalpel

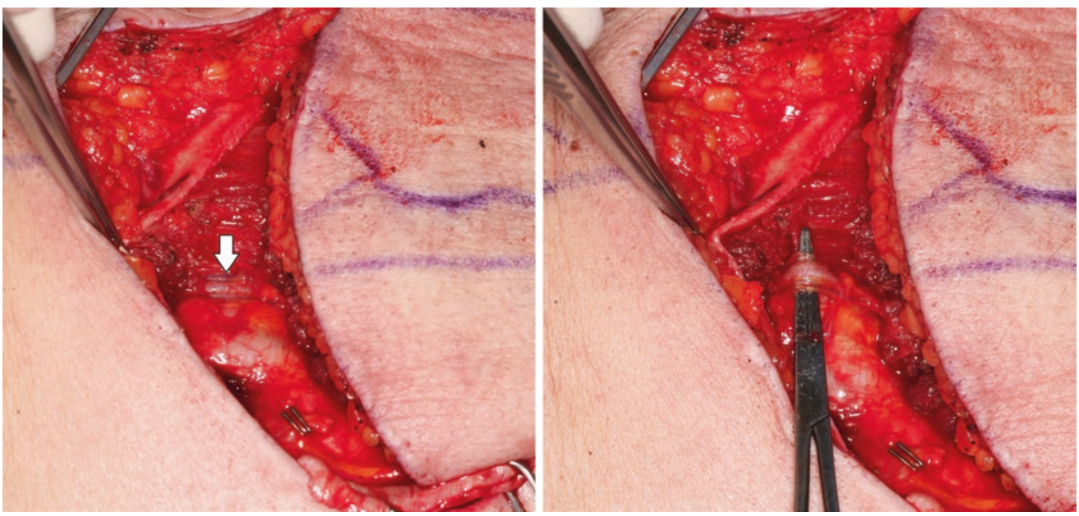


Fig. 6.15 Step 4: identification and section of DSEA in the superior portion of the sectioned muscle

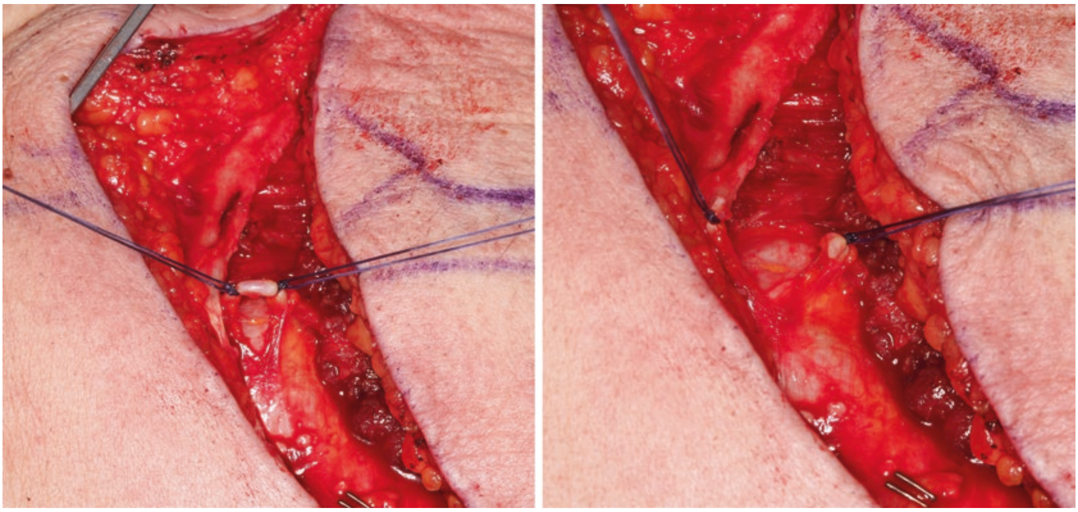


Fig. 6.15 (continued)

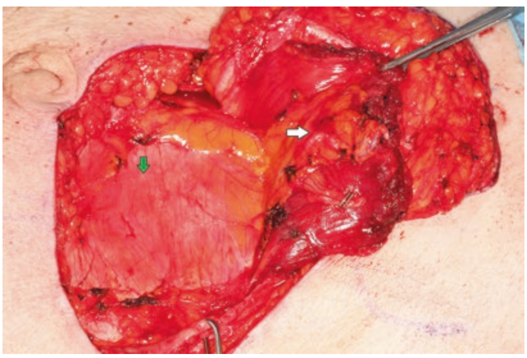


Fig. 6.16 Step 5: flap is raised from cephalad to caudal preserving integrity of posterior rectus sheath (green arrow). Pedicle is visible (white arrow)

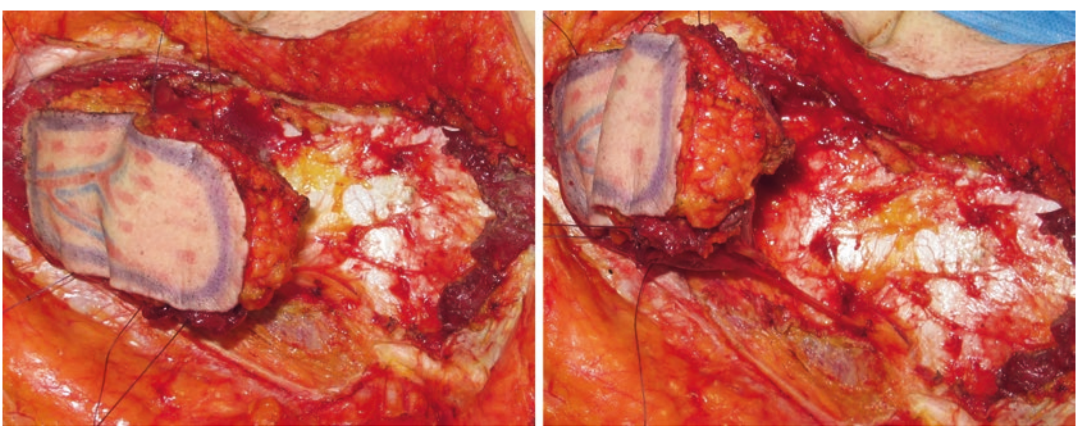


Fig. 6.17 Step 5: segmental nerves from intercostal nerves are dissected

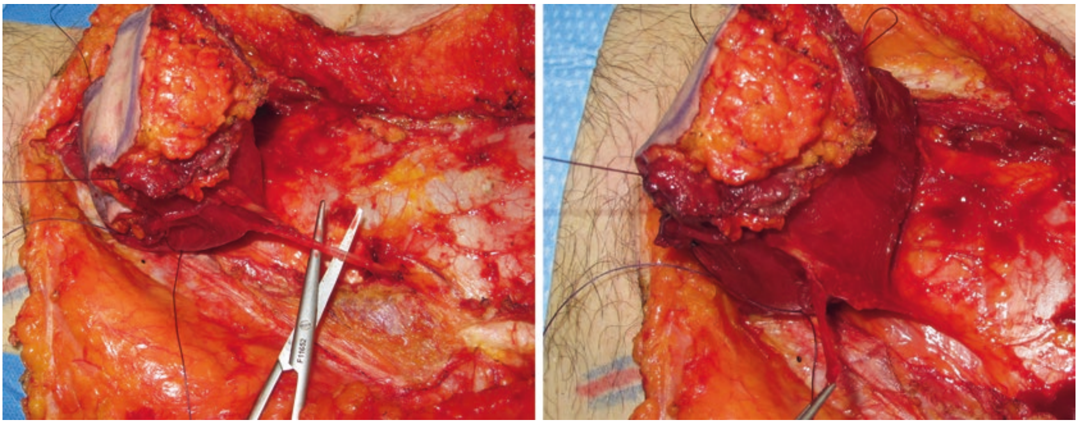


Fig. 6.17 (continued)

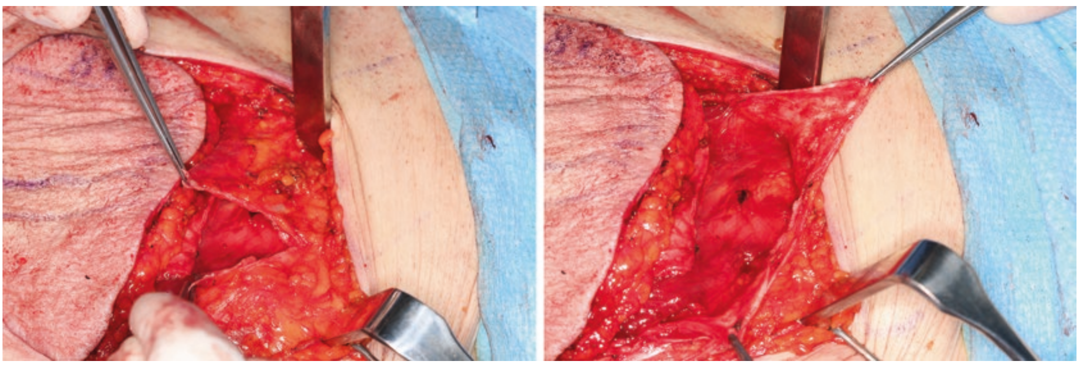


Fig. 6.18 Step 6: verical incision of the inferior portion of anterior rectus sheath

6.5 Donor Site Closure

Closure of the donor site is an essential step to avoid postoperative complications as incisional hernia. As already mentioned before, it is crucial to preserve the anterior rectus muscle sheath as much as possible, especially below the arcuate line.

Abdominal wall reinforcement should always be performed using a Prolene mesh prosthesis, fixed at the anterior rectus sheath (Fig. 6.24).

Final appearance of the abdominal wall after defect closure (Fig. 6.25).

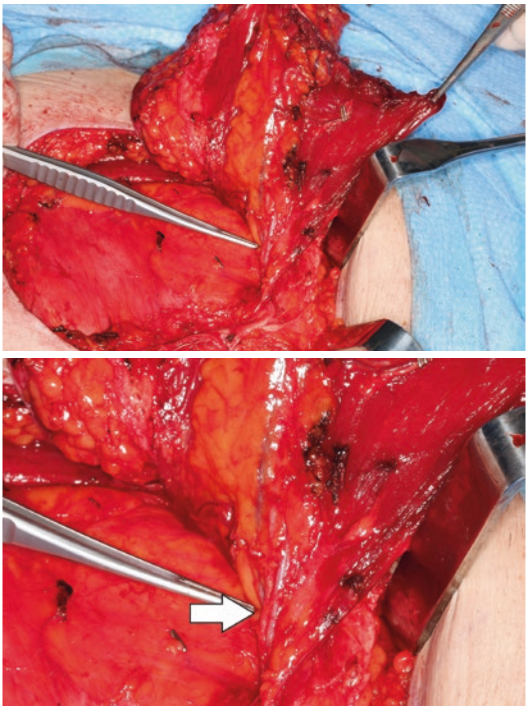


Fig. 6.19 Step 7: DIEA and veins are cleary visible (white arrow)

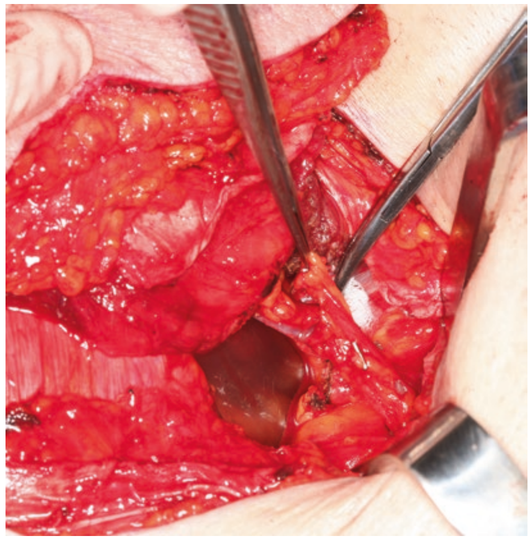


Fig. 6.20 Step 7: pedicle is surrounded by fat tissue

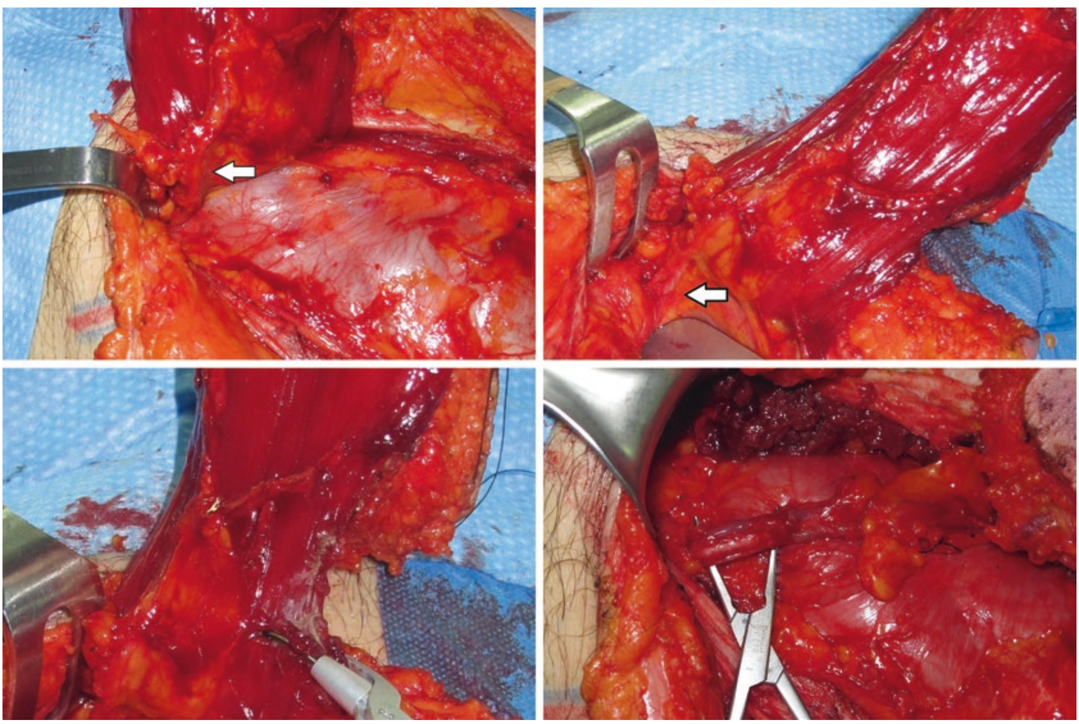


Fig. 6.21 Step 7: pedicle is follow until 2 venae comitantes join in a single bigger vein 1–2 cm before the external iliac vein. Inferior portion of rectus muscle is transected

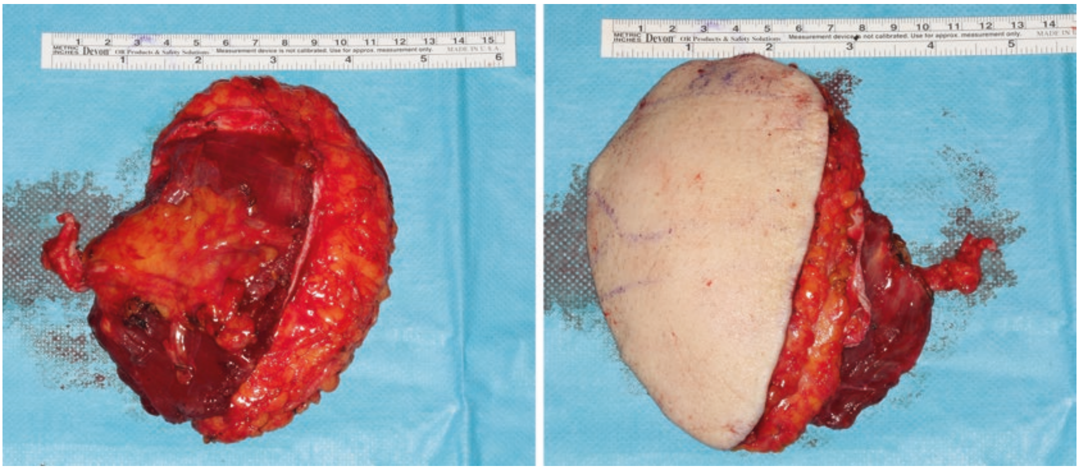
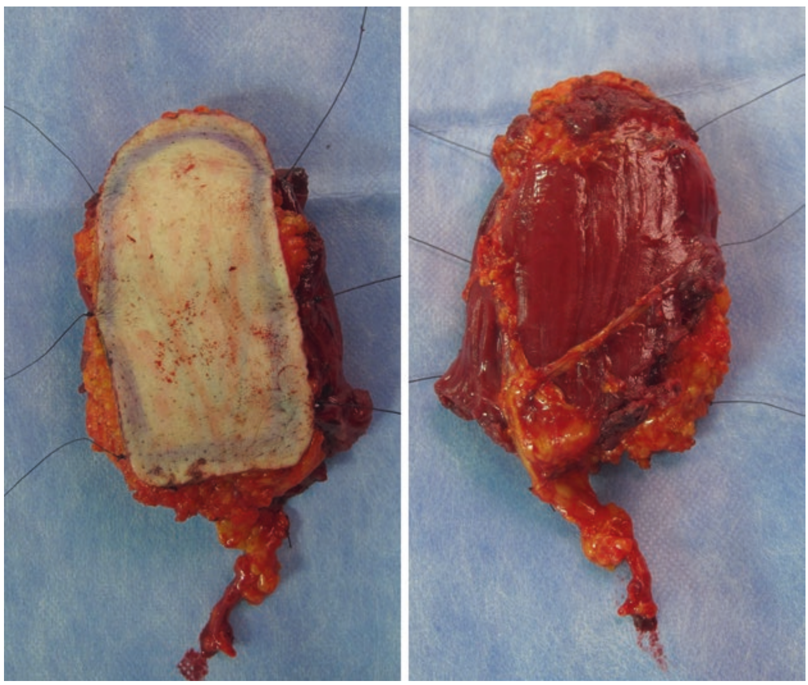


Fig. 6.22 Step 8: final appearance of the TRAM

Fig. 6.23 Step 8: final appearance of the VRAM



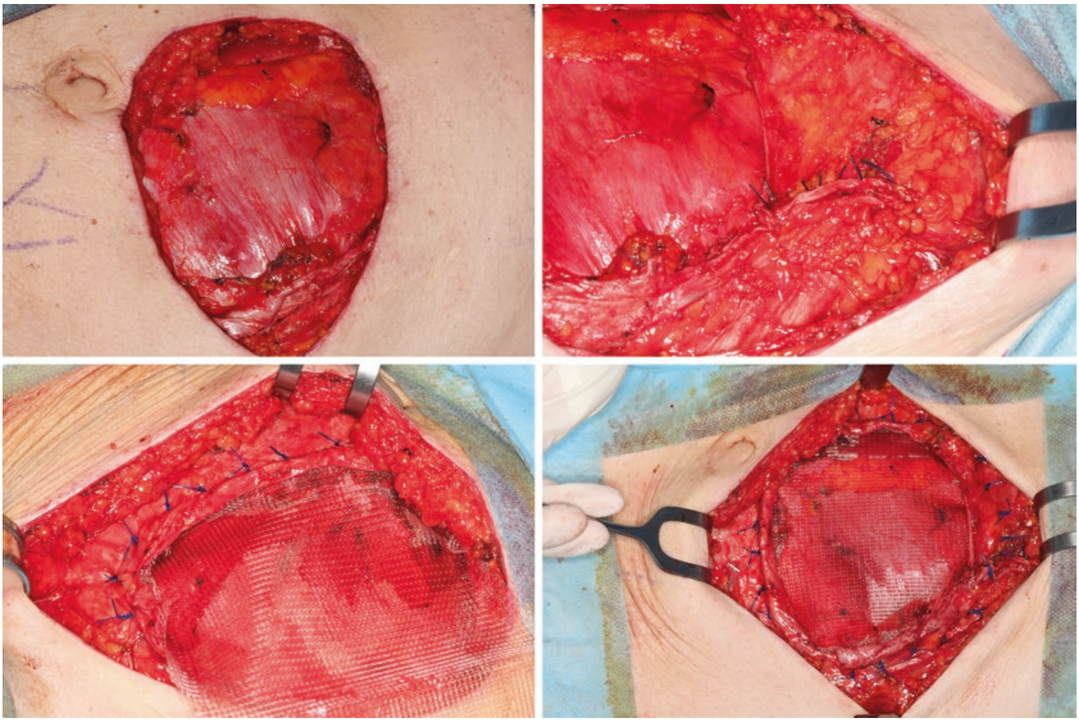


Fig. 6.24 Donor site closure with mesh prosthesis

Fig. 6.25 Donor site appearance at the follow-up

References

1. Milloy FJ, Anson BJ, McAfee DK. The rectus abdominis muscle and the epigastric arteries. Surg Gynecol Obstet. 1960;110:293–302.
2. Baumann DP, Lin HY, Chevray PM. Perforator number predicts fat necrosis in a prospective analysis of breast reconstruction with free TRAM, DIEP, and SIEA flaps. Plast Reconstr Surg. 2010;125(5):1335–41.
3. Kaufman T, Hurwitz DJ, Boehnke M, Futrell JW. The microcirculatory pattern of the transverse-abdominal flap: a cross-sectional xerographic and CAT scanning study. Ann Plast Surg. 1985;14(4):340–5.
4. Yamamoto Y, Minakawa H, Kokubu I, Kawashima K, Sugihara T, Satoh N, Fukuda S. The rectus abdominis myocutaneous flap combined with vascularized costal cartilages in reconstructive craniofacial surgery. Plast Reconstr Surg. 1997;100(2):439–44.

7 The Gracilis Flap

M. Cherubino, D. Sallam, and P. L. Tos

7.1 Introduction

The *gracilis* is a thin muscle of the thigh. The most common indication for *gracilis* free flap in head and neck reconstruction is for dynamic mid and lower facial reanimation for long-standing facial paralysis [1, 2].

Its advantages include a consistent anatomy, a hide donor-site scar, limited functional morbidity, and simultaneous two-team surgical approach. The technique, however, has some drawbacks that must be considered: the relative short pedicle, possible numbness of the medial thigh, potential for chronic lymphedema, contour deformities of the medial thigh, and widening of scar. The *gracilis* muscle and the ipsilateral soft tissues are based on a single constant neurovascular pedicle represented by a branch of the medial circumflex artery and its venae. The gracilis free flap has been generally used as a muscular, rather than a musculocutaneous, free flap because of the unpredictable distribution of its perforating vessels; however, the transverse cutaneous island has showed affordability. In the clinical setting, preoperative or intraoperative Doppler is used to mark the skin perforator. Alternatively, if cutaneous coverage is required, the muscle free flap can be covered by skin grafts.

M. Cherubino (✉) · D. Sallam
Plastic Surgery Department, University of Insubria, Varese, Italy

P. L. Tos
Department of Orthopaedics and Traumatology for Hand, ASST Gaetano Pini, Milan, Italy

7.2 Anatomy

The gracilis muscle measures approximately 25–27 cm in length and 6 cm proximally to 4 cm distally in width. It is a superficial muscle of the thigh adductor muscle group on the medial surface of the thigh. It is located just posteromedial to the adductor longus and is involved in thigh adduction and hip flexion. It runs from both the inferior ramus of the pubis and ischium to the medial surface of the tibia, contributing to the *tendinous pes anserinus*.

The vascular supply is provided by a single arterial branch arising from the adductor branch of the *profunda femoris* vessels or the medial circumflex femoral vessels and two *venae comitantes*. This pedicle runs on the deep surface of the muscle. Its length ranges from 5 to 7 cm, while the caliber of the artery between 1.5 and 2.5 mm. Usually, the dominant vascular pedicle could be supported by secondary small superficial femoral vessel branches which feed the middle and lower thirds of the muscle. These are always sacrificed during the dissection because the dominant pedicle alone can supply the entire *gracilis* muscle.

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https://doi.org/10.1007/978-3-030-29582-0_7

Cutaneous perforators are usually located in the proximal region of the muscle. The skin paddle can be oriented longitudinally along the muscle or transversely at the proximal third of the muscle. A skin paddle up to 20 cm × 10 cm can be used with this flap.

Its innervation is provided by the anterior branch of the obturator nerve which divides into multiple segments before entering the muscle, potentially allowing the harvest of different functionally units within the muscle.

7.3 Surgical Technique

7.3.1 Preoperative Markings (Fig. 7.1)

The patient should be premarked in the standing position in order to easily identify the muscle when supine. Reference consists in a line connecting the pubic tubercle and the medial condyle of the knee. The gracilis tendon is one of the tendons that form the “pes anserine”. Operative field should include the pubic symphysis and the medial condyle of the femur. The thigh should be included circumferentially. The patient is positioned supine with the leg abducted, and the knee slightly flexed. If a skin paddle is needed, Doppler ultrasound should be performed in order to find and choose a proper perforating vessel. Then, a vertically elliptical skin paddle based on the perforator is marked. The paddle could be also oriented longitudinally but posterior to the reference line and posterior to the saphenous vein.

7.3.1.1 Step 1

The entrance of the pedicle on the deep surface of the gracilis muscle is then marked 10 cm below the pubic tubercle. The skin is incised at this level, following the premarked line between the pubic tubercle and the medial condyle. The dissection is then continued through subcutaneous tissue until the muscular fascia is reached. The neurovascular pedicle is located at the anterior part of the upper third of the muscle 10 cm below the ischium (Fig. 7.2).

7.3.1.2 Step 2

At this point, the septal junction between the gracilis and adductor longus must be identified. This space is then entered by retracting the two muscles from each other, and the pedicle to the gracilis is identified in this areolar plane (Fig. 7.3).

7.3.1.3 Step 3

Once the vascular supply has been safely located as protected, the muscle dissection can be completed. In most of cases, a second small incision approximately 10 cm proximal the medial condyle is made, in order to reach the distal part of the muscle (Fig. 7.4).

Fig. 7.1 Preoperative setting and flap design

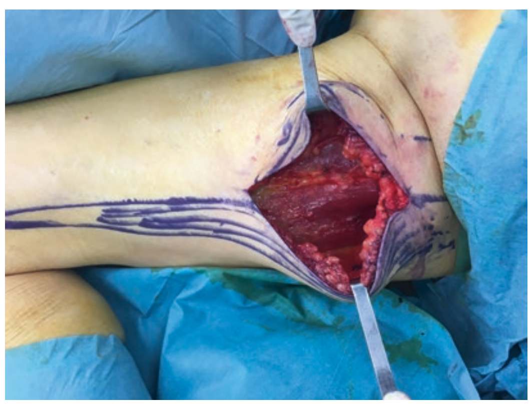

Fig. 7.2 First surgical step. After dissection of the subcutaneous tissue, the gracilis muscle is identified and separated

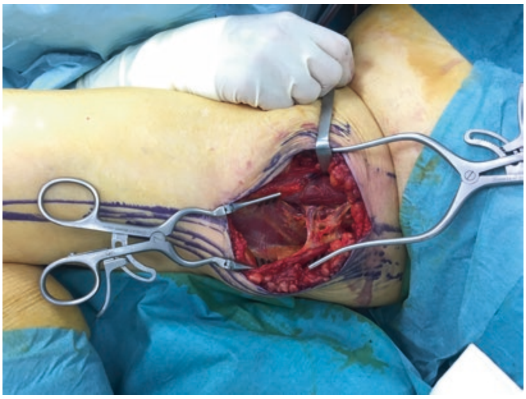

Fig. 7.3 Second surgical step

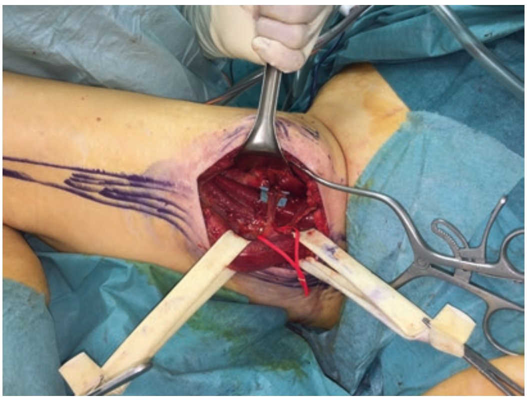

Fig. 7.4 Third surgical step

7.3.1.4 Step 4

The gracilis muscle-tendon unit is then divided, and the gracilis muscle is finally separated from the adductor longus and adductor magnus muscles working from a distal to proximal direction. Minor pedicles are ligated. Closure of the wound is done in layers over suction drains. The patient can be allowed to walk after 5 days (Fig. 7.5).

7.3.2 TUG Flap

As the gracilis muscle free flap has gained wide popularity due to its predictable vascular anatomy and minimal donor-site morbidity, by contrast, the myocutaneous one is less used because of previously documented unreliability of the overlying skin island [3–5]. More recently, two variations of the myocutaneous flap have been described: the transverse island [6] and the vertically oriented one [3]. Usually, when a myocutaneous flap is required, the transverse upper gracilis (TUG) flap represents the most common variation of the simple *gracilis* flap. It was described first by Yousif et al. [6] in 1992, with the first clinical reports in 1993 [7]. The skin paddle and underlying fat are horizontally oriented as a wide ellipse over the proximal upper one-third of the *gracilis* muscle. This kind of skin orientation has the main advantage of a low donor-site morbidity but has also some limitations such as the potential damage to the lymphatic drainage of the leg, the limited amount of tissues, and the widening and lowering of the donor-site closure scar with time [8–11]. The technique consists in planning the skin paddle transversely, with the widest point centered over the *gracilis* muscle. The operating surgeon must be careful not to resect too much skin, since closure can be difficult. The dissection starts anteriorly in the subcutaneous tissue. The saphenous vein can be included in the flap if necessary. Once the edge of the adductor longus is reached, the muscular fascia is incised, and the pedicle to the *gracilis* is identified under the adductor longus. Now, the dissection is started posteriorly until the margin of the *gracilis* is reached. Finally, the proximal and distal muscles are divided. And the pedicle is traced to its origin to gain length as necessary.

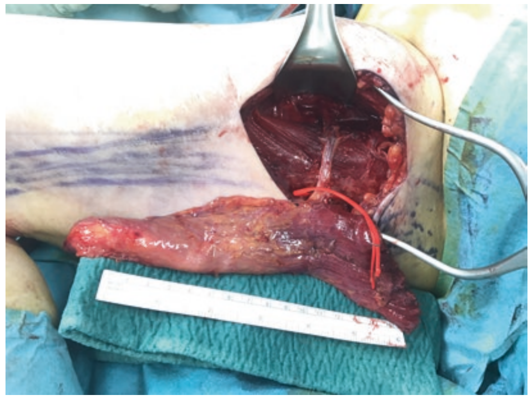

Fig. 7.5 Final appearance of the flap

References

1. Lin CH, Wallace C, Liao CT. Functioning free gracilis myocutaneous flap transfer provides a reliable single-stage facial reconstruction and reanimation following tumor ablation. Plast Reconstr Surg. 2011;128(3):687–96.
2. Hadlock TA, Malo JS, Cheney ML, Henstrom DK. Free gracilis transfer for smile in children: the Massachusetts Eye and Ear Infirmary Experience in excursion and quality-of-life changes. Arch Facial Plast Surg. 2011;13(3):190–4.
3. Kropf N, Cordeiro CN, McCarthy CM, Hu QY, Cordeiro PG. The vertically oriented free myocutaneous gracilis flap in head and neck reconstruction. Ann Plast Surg. 2008;61(6):632–6. https://doi.org/10.1097/SAP.0b013e31816d82c0.
4. Giordano PA, Abbes M, Pequignot JP. Gracilis blood supply: anatomical and clinical re-evaluation. Br J Plast Surg. 1990;43:266–72.
5. Harii K, Ohmori K, Sekiguchi J. The free musculocutaneous flap. Plast Reconstr Surg. 1976;57:294–303.
6. Yousif NJ, Matloub HS, Kolachalam R, Grunert BK, Sanger JR. The transverse gracilis musculocutaneous flap. Ann Plast Surg. 1992;29:482–90.
7. Yousif NJ. The transverse gracilis musculocutaneous flap. Ann Plast Surg. 1993;31:382.
8. Schoeller T, Huemer GM, Wechberger G. The transverse musculocutaneous gracilis flap for breast reconstruction: Guidelines for flap and patient selection. Plast Reconstr Surg. 2008;122:29–38.
9. Pülzl P, Schoeller T, Kleenwein K, Wechselberger G. Donor-site morbidity of the transverse musculocutaneous gracilis flap in autologous breast reconstruction: Short-term results. Plast Reconstr Surg. 2011;128:233e–42e.
10. Buntic RF, Horton LM, Brooks D, Althubaiti GA. Transverse upper gracilis flap as an alternative to abdominal tissue breast reconstruction: Technique and modifications. Plast Reconstr Surg. 2011;128:607e–13e.
11. Fattah A, Figus A, Mathur B, Ramakrishnan VV. The transverse myocutaneous gracilis flap: Technical refinements. J Plast Reconstr Aesthet Surg. 2010;63:305.

Part III

Perforator Flaps

8 Anterolateral Thigh Flap

G. Molteni, L. Lanaro, M. Ghirelli, A. Fior, G. Giampaoli, and R. Pellini

8.1 Anatomy

8.1.1 Muscles

The anterolateral thigh (ALT) compartment has four anatomical limits: the rectus femoral muscle medially, the iliotibial tract laterally, the anterior superior iliac spine (ASIS) superiorly, and the lateral femoral condyle inferiorly. A superficial fascia, with subcutaneous tissue, covers the entire muscular structure. The deepest fascia in the lateral part is formed by the tensor muscle of the fascia lata connected with the fascia lata to compose the iliotibial band, which provides stability in the knee joint.

G. Molteni
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

L. Lanaro · A. Fior · G. Giampaoli
Maxillofacial Surgery and Dentistry, University Hospital of Verona Borgo Roma, Verona, Italy

M. Ghirelli (✉)
Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital of Modena, Modena, Italy

R. Pellini
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

The muscles present in this compartment are the tensor fascia lata muscle originating from the ASIS that is superolaterally positioned, the sartorial muscle that originates from the ASIS and crosses the thigh up to the medial portion of the tibia, the rectus femoris muscle located in the medial portion, and the vastus lateralis muscle located between the rectus femoris muscle and the ileopubic tract (Fig. 8.1).

8.1.2 Artery

The deep femoral artery is a branch of the femoral artery that travels down the thigh closed to the femur, running between the pectineus and the adductor longus. From the lateral site, soon after its origins, arises the lateral circumflex femoral artery (LCFA) that passes horizontally between femoral nerve branches and, more rarely, posterior to them. LCFA usually courses anterior to the femoral neck and behind the sartorius and rectus femoris muscles where it divides into ascending, transverse, and descending branches. The descending branch of LCFA runs downward on the vastus intermedius, behind the rectus femoris, and medial to vastus lateralis.

Along its course, it gives rise to intramuscular branches, the vastus lateralis and septocutaneous branches, and the intermuscular septum between rectus femoris and vastus lateralis. Perforating arteries from the intramuscular branches and septocutaneous arteries supply the overlying fascia and skin.

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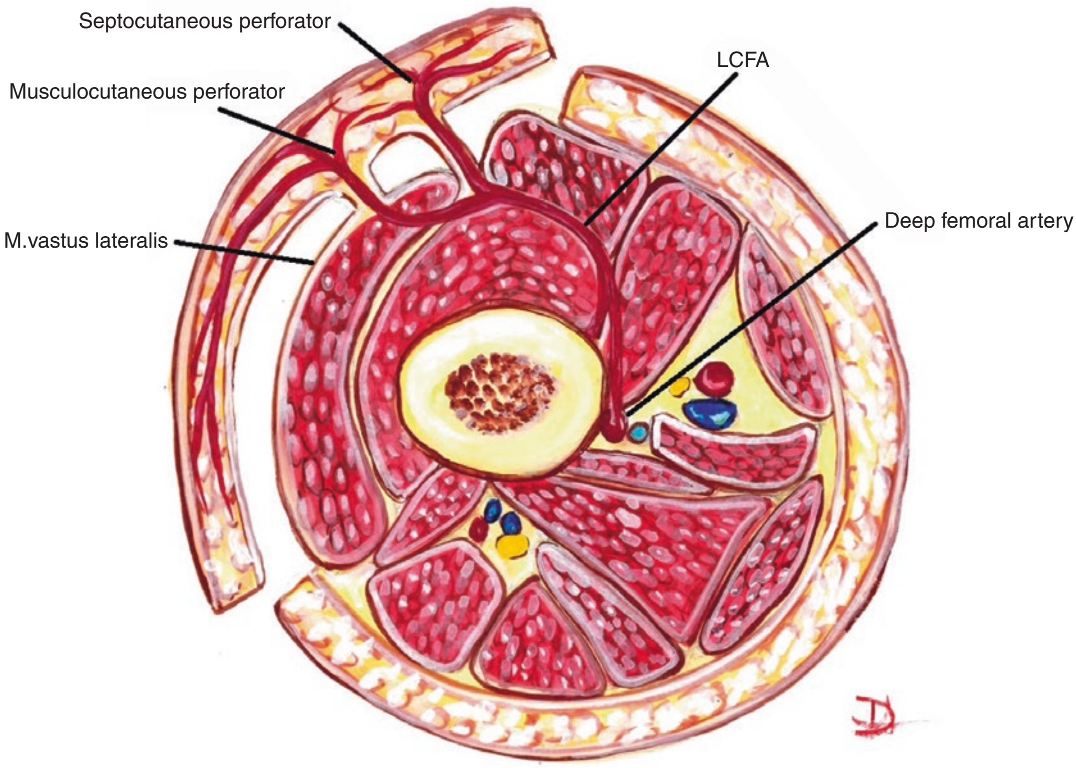

Fig. 8.1 Anatomy of perforator vessels in ALT flap

All these 3–5 ramifications, with an average diameter of 0.3 mm, form a rich network of vascularization in subcutaneous layers of the anterolateral thigh. The terminal long branch descending in the vastus lateralis ends in the superior lateral genicular artery which anastomoses with the femoropopliteal system.

8.1.3 Venous System

The anterolateral thigh has two systems of venous drainage: a superficial system composed of anterior femoro-cutaneous vein called anterior accessory saphenous vein and a deep system composed of two venae comitantes accompanying the perforator artery.

The anterior accessory saphenous vein commences at the distal portion of the lateral thigh and moves up in a constant location deep to the subcutaneous fat plane. It runs up to gain access to the great saphenous vein (GSV) or alternatively to the femoral vein just before that vein enters the saphenous opening.

Venae comitantes draining a series of smallest veins from a sort of subcutaneous net and from the vastus lateralis muscle give rise to the deep femoral vein that, together with femoral vein, are tributaries of the common femoral vein.

Deep systems are able to drain the blood from the skin of the thigh much more than the superficial system. Because of the poor connections between the venae comitantes and the superficial veins, only the deep system is used to drain the flap.

8.1.4 Nerves

The cutaneous innervation of the lateral thigh is derived from the lateral femoral cutaneous nerves. It is a nerve that originates from the lumbar plexus, specifically from the dorsal divisions of L2–L3; it emerges from the lateral border of the psoas major and crosses the iliacus muscle obliquely, toward the anterosuperior iliac spine. It reaches the lacuna musculorum passing under the inguinal ligament, into the thigh. It runs over the sartorius muscle where it divides into an anterior and a posterior branch. The anterior branch becomes superficial about 10 cm below the inguinal ligament and distributes branches to the anterior and lateral skin of the thigh. The posterior branch pierces the fascia lata and subdivides into filaments supplying the skin of the lateral and posterior surfaces of the thigh.

The cutaneous innervation of the anterior thigh is derived from the femoral nerve that provides also the innervation to the muscles that extend the knee. The femoral nerve splits into an anterior and a posterior branch under the inguinal ligament, into the thigh.

The anterior division of the femoral nerve gives off anterior cutaneous and muscular branches. The anterior cutaneous branches comprise the intermediate and medial femoral cutaneous nerve supplying the anterior and medial skin of the thigh. Muscular branches serve the pectineus and the sartorius muscles.

The posterior division of the femoral nerve provides innervation to the quadriceps femoris and the knee.

Muscular branches include the branch to the rectus femoris entering the upper part of the inner surface of the muscle; the branch to the vastus medialis descending lateral to the femoral vessels; the branches to the vastus intermedius, two or three in number, entering the anterior surface of the muscle about the middle of the thigh; and a large branch to the vastus lateralis accompanying the descending branch of LCFA and venae comitantes to the lower part of the muscle. It gives off a long slender articular filament to the knee that penetrates the capsule of the joint on its anterior aspect.

8.2 Analytical Factors and Technical Considerations

Yu described a useful classification of the vascular anatomy of ALT flap and reported a number of cutaneous perforators present in each flap averaged two (Fig. 8.2) [1].

1. The Location of the cutaneous perforators.
   (a) *Type A*: Most proximal (perforator located 18.9 ± 3.5 cm from ASIS).
   (b) *Type B*: Middle (perforator located 24.3 ± 5.4 cm from ASIS).
   (c) *Type C*: Most distal (perforator located 28.7 ± 3.5 cm from ASIS).

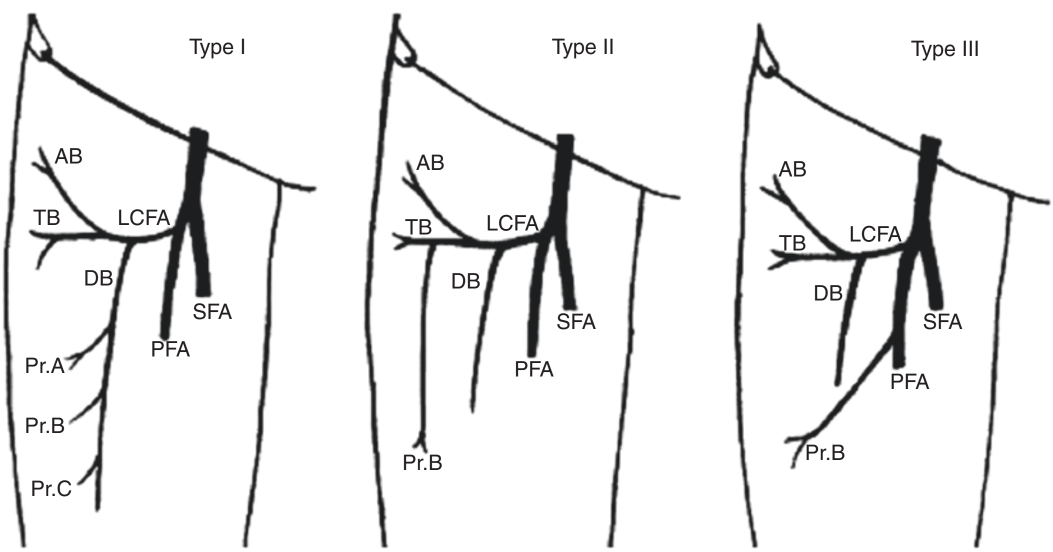

Fig. 8.2 Vascular variations

2. The Origin of the Cutaneous Perforators.
   (a) *Type I* (90% of the patients): It arises from the descending branch of the LCFA. In 90% of cases, there are musculocutaneous perforators through the medial portion of vastus lateralis muscle; in 10%, there are septocutaneous perforators. The musculocutaneous ones have a 2–3 cm course through the vastus lateralis muscle medial to the lateral course. For this reason, it is relatively easy to dissect.
   (b) *Type II* (5–10%): In most of the cases, the perforators are musculocutaneous perforators that take a long intramuscular course through the vastus lateralis muscle. The superior-to-inferior-oriented intramuscular course can be up to 10 cm long, before they reach the thigh skin. Because of their long intramuscular course, type II musculocutaneous perforators are the most difficult to dissect.
   (c) *Type III* (1–5%): Cutaneous perforators arise directly from the profunda femoris artery. In this type, the perforators are all intramuscular and have very small caliber unsuitable for microvascular anastomosis. The perforators located in the distal thigh provide a longer vascular pedicle than those that arise in the proximal thigh.

8.3 Flap Harvesting

8.3.1 Preoperative Management

The occurrence of acute vascular insufficiency when harvesting an anterolateral thigh free flap is exceedingly rare. There are no substantial differences in flaps harvested from the left or right side, although previous surgery, scars, injury, fractures, and burns may contraindicate the use of a specific thigh. When possible, it is preferable to have the operating thigh on the contralateral side to the resection in order to create more space for two surgical teams to work simultaneously. At least the patient's preference is taken into account. At the admission, hospital personnel must be instructed to shave the chosen thigh.

The patient must be counseled about the evidence of the flap loss and about the donor site sequelae and, in particular, the visibility of the thigh scar with a possible poor cosmetic result, the possible use of a skin graft for the donor site closure, and the possibility of temporary or permanent variable sensory loss of the posterolateral portion of the thigh.

8.3.2 Patient Positioning

The thigh must be slightly abducted and internally rotated to facilitate surgical approach (Fig. 8.3).

8.3.3 Flap Design

Flap design is marked based on anatomical knowledge. The intermuscular septum between rectus femoris and vastus lateralis runs under a virtual line that joins the superior lateral aspect of the patella and the anterosuperior iliac spine that are easily identified by palpation (Fig. 8.4).

On the midpoint of this line, it is customary to draw a circle of 3 cm radius to identify the area where most frequently the perforator artery enters in the suprafascial space. The skin vessels are often found in the inferolateral quadrant of the circle with a Doppler control (Fig. 8.5).

The size and shape of the skin paddle are then designed on the thigh, often with a template from the defect, around the defined skin vessels. Although the axis of the flap should be centered over the artery landmark, it can be designed with

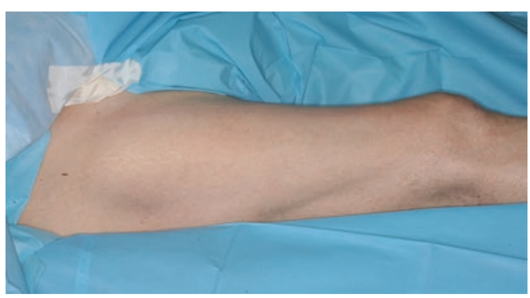

Fig. 8.3 Leg position

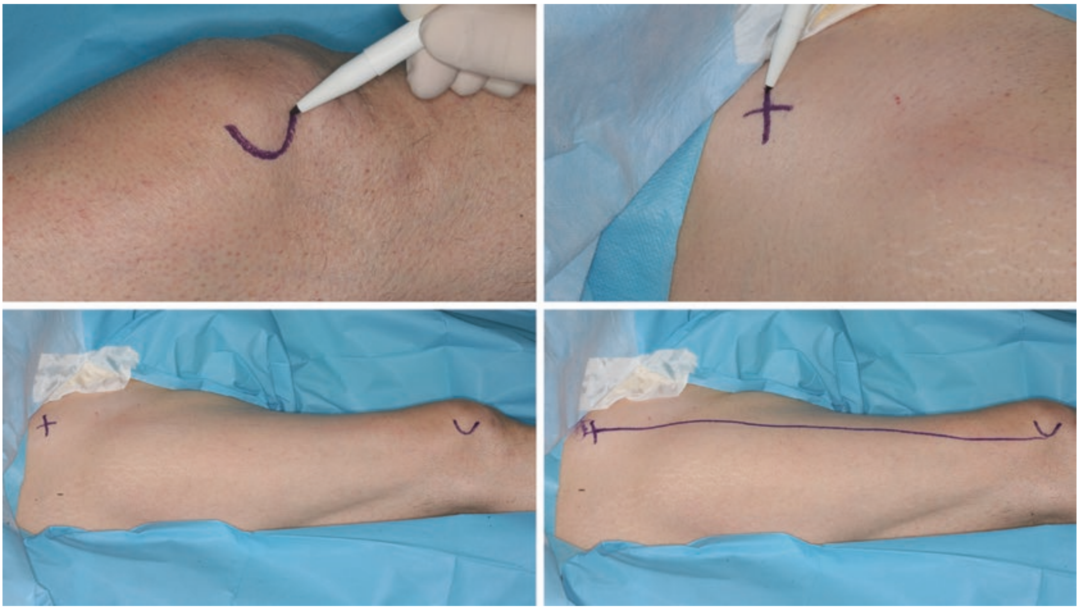

Fig. 8.4 Flap design: Anatomical landmark identification

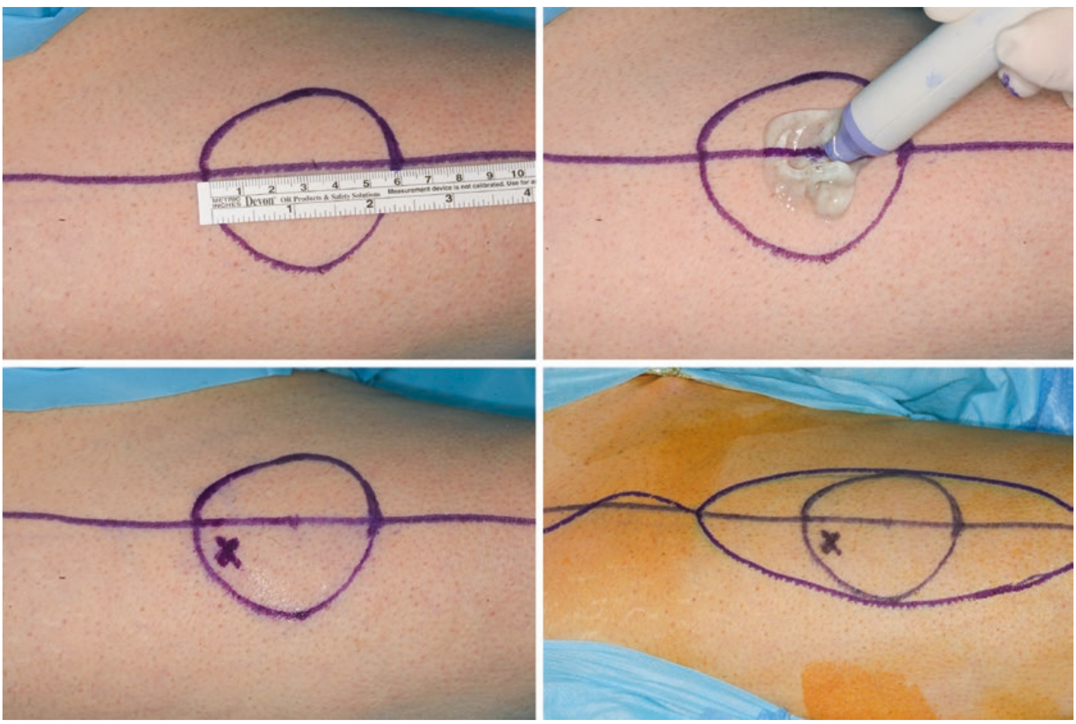

Fig. 8.5 Flap design: Doppler identification of the perforator vessels

the skin vessels in an eccentric position if a longer pedicle is required.

The length of the pedicle is determined considering the distance of the reconstruction site from the final microanastomosis site, avoiding undesirable kinking of the vessels. For example, the pedicle length will be quite short in case of hypopharyngeal reconstruction and longer in case of tongue reconstruction with microanastomosis on the contralateral neck.

8.4 Surgical Steps

8.4.1 Step 1

After the flap is marked, the skin incision is performed on the medial border of the paddle. Dissection proceeds in subcutaneous tissue until the rectus femoris fascial plane. The fascial incision is usually performed if a fascio-cutaneous flap is schedule. Although a pure cutaneous-subcutaneous flap is possible to make, the included fascial plane in the dissection protects the flap against damage, tearing, and twisting of the vessels (Fig. 8.6).

8.4.2 Step 2

After fascial incision, some stay suture is performed between subcutaneous tissue and fascia itself in order to avoid slicing of the different layers (Fig. 8.7).

8.4.3 Step 3

Subfascial dissection is performed on the surface of the rectus femoris in a lateral direction reaching the previously Dopplered perforator vessels. Cauterization or vessel ligature must not be performed during this step in order to not cut out the pedicle (Fig. 8.8).

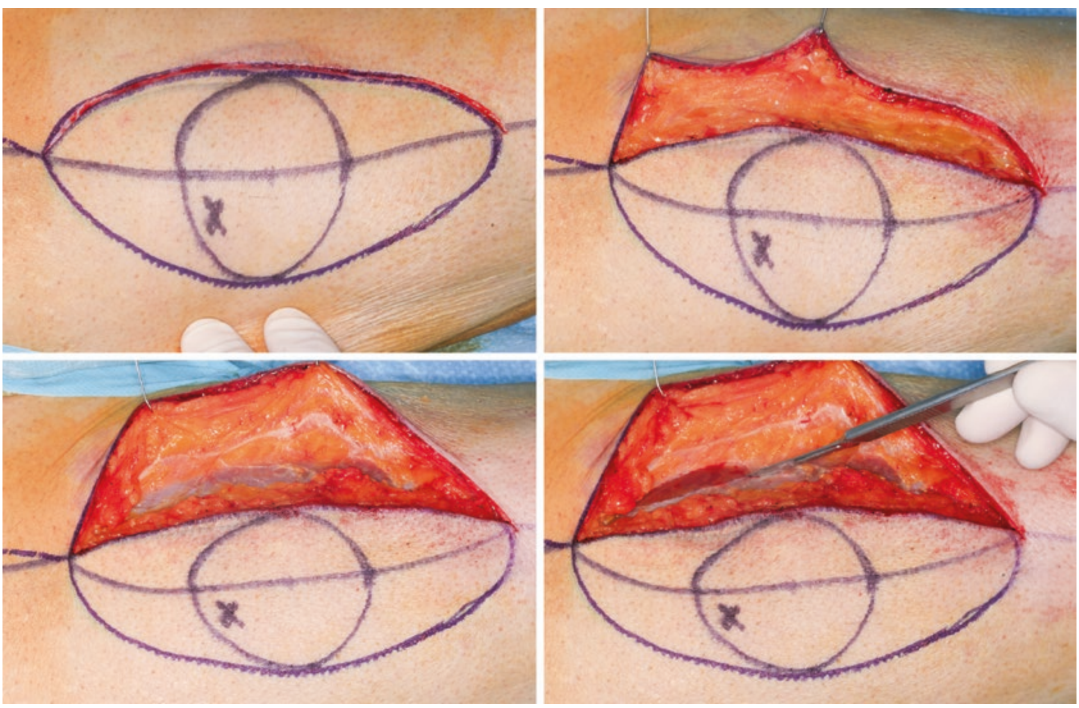

Fig. 8.6 Step 1: Skin incision, subcutaneous flap harvesting and incision of the rectus femoris fascial plane

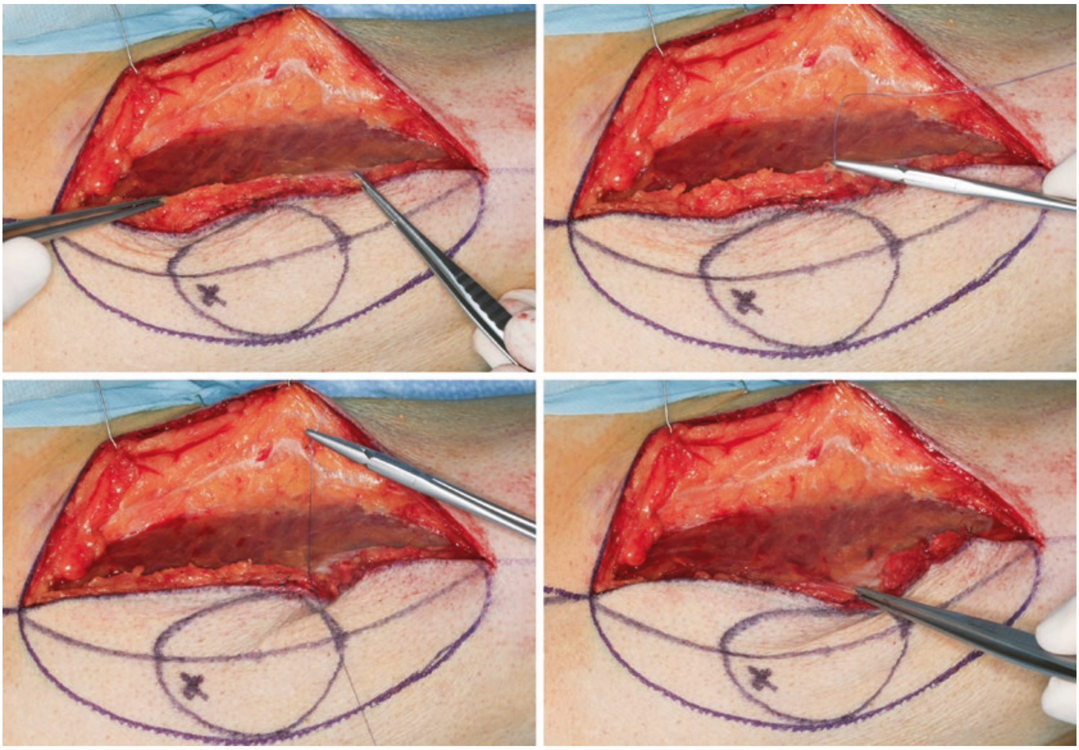

Fig. 8.7 Step 2: Fascia and skin are suture to prevent sliding

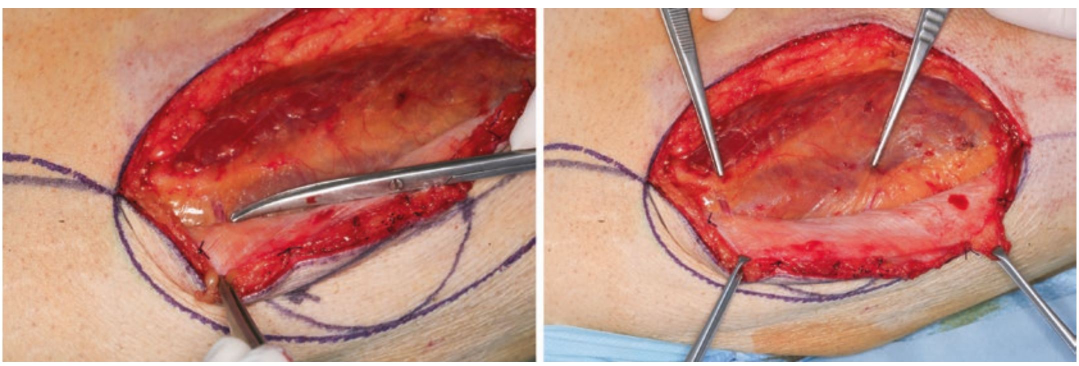

Fig. 8.8 Step 3: Identification of the perforator vessels

8.4.4 Step 4

Intramuscular dissection is performed in order to follow the pedicle in a retrograde fashion until the descending branch of LCFA. If perforators are pure septocutaneous artery, the intramuscular dissection is not required. Follow the fascial plane where it reflects into intermuscular septum and where it is comfortable to identify where the pedicle runs, until the descending branch of LCFA (Figs. 8.9, 8.10 and 8.11).

8.4.5 Step 5

After identifying suitable vessels and confirming its course to the descending branch of LCFA, the complete dissection of the vessels and comitantes veins is performed; small collateral branches are carefully ligated and accessory pedicle is closed. If two different vessels merge running deep into the thigh, a careful dissection can preserve both of them (Fig. 8.12).

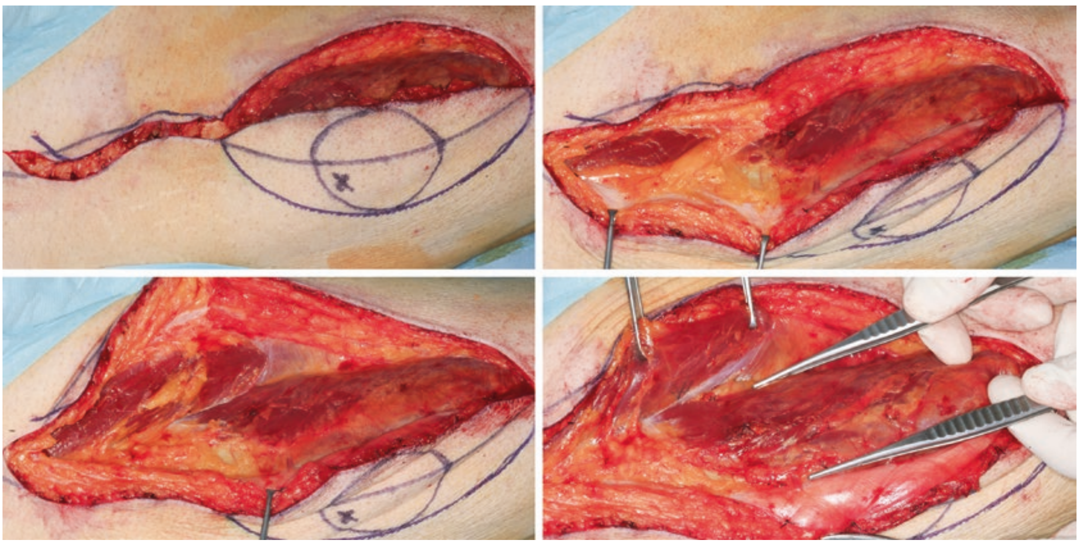

Fig. 8.9 Step 4: Intramuscolar direction of perforator pedicle is identify

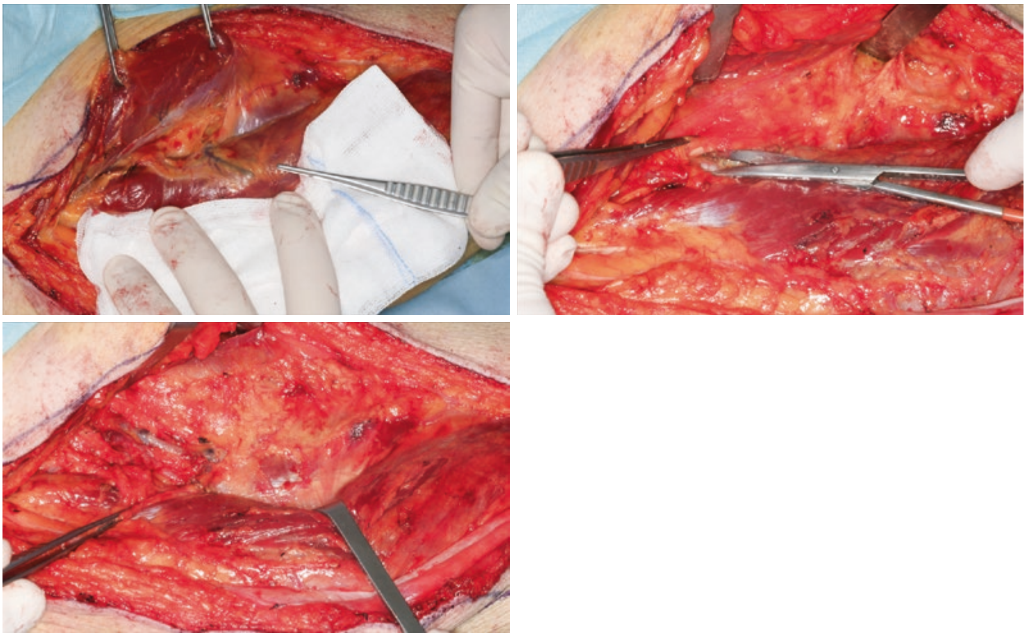

Fig. 8.10 Step 4: Identification of the deep femoral artery

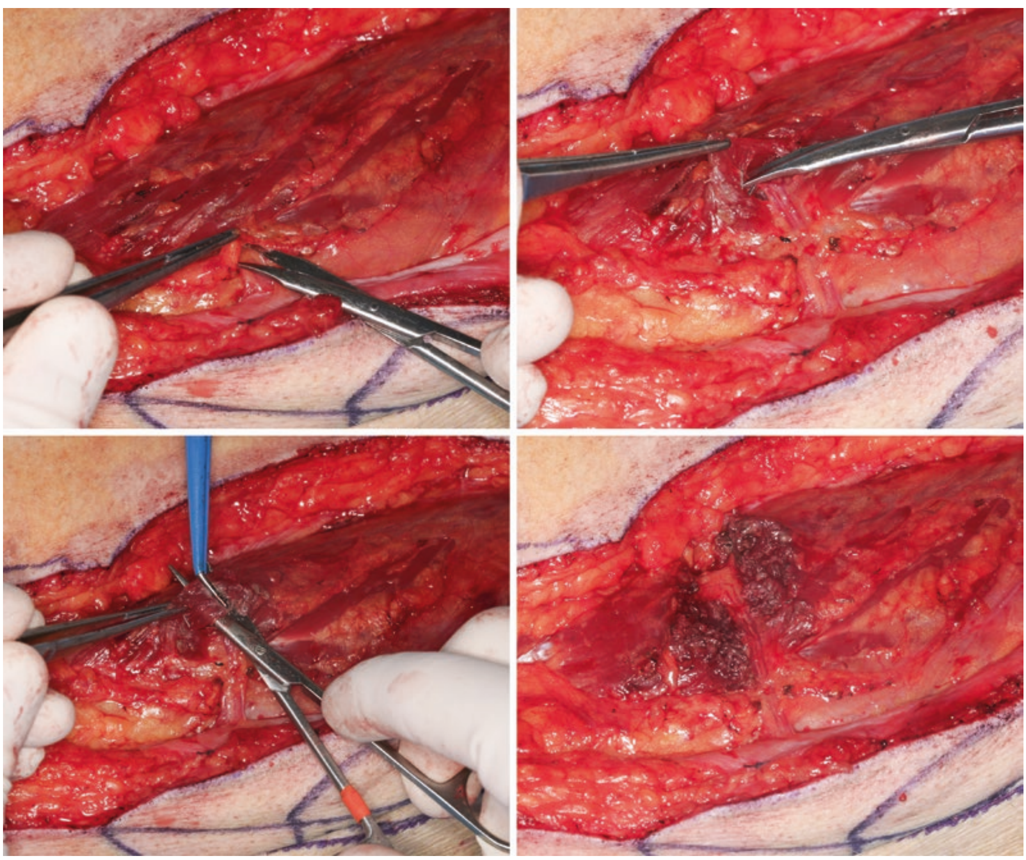

Fig. 8.11 Step 4: Intramuscular dissection dissection of the pedicle in a retrograde fashion

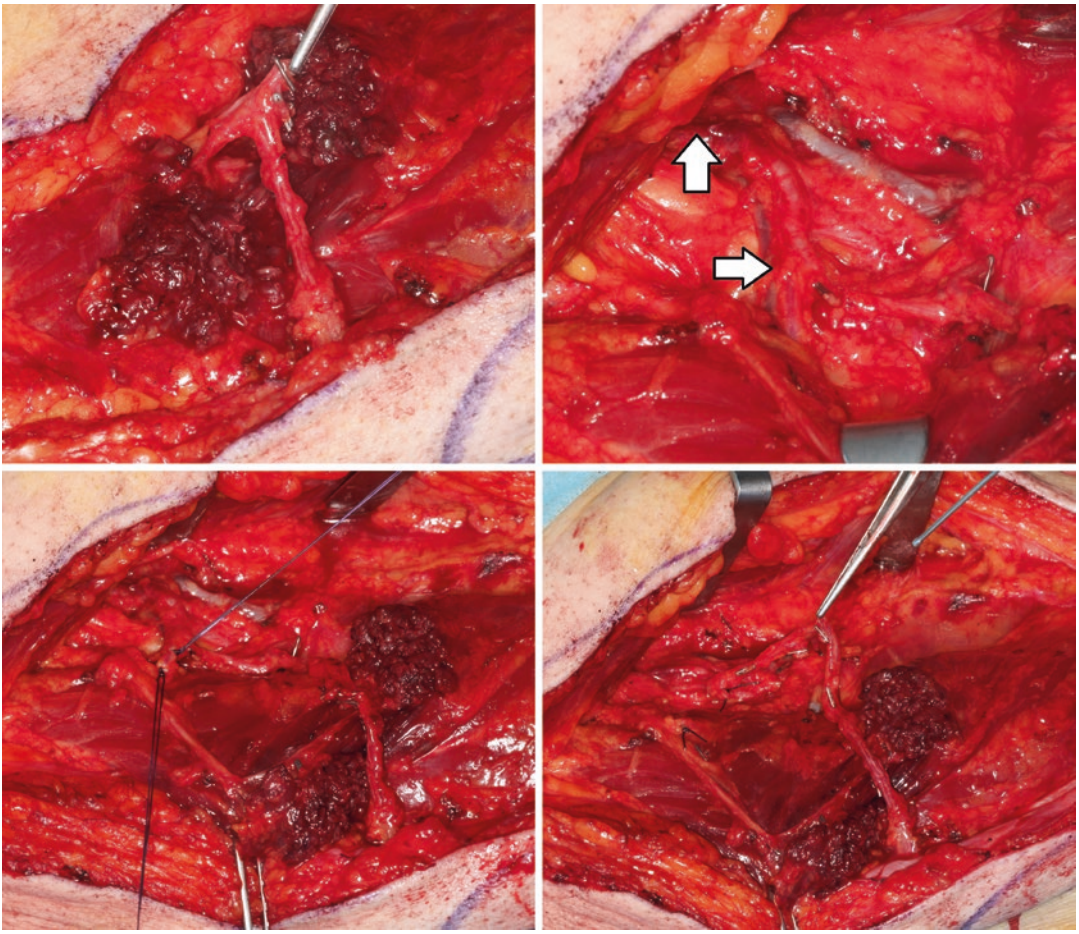

Fig. 8.12 Step 5: Complete dissection of the flap's pedicle

8.4.6 Step 6

Lateral incision is then made, with a subcutaneous dissection and vastus lateralis fascia incision. Traction on the pedicle is always avoided, and constant attention to the pedicle during dissection is a must. Stay suture is performed as explained in step two (Fig. 8.13 and 8.14).

8.4.7 Step 7

At this point, the descending branch of LCFA is dissected from distal to proximal by ligation/cauterization and transection of the branches that supply the muscles. Nerve branches to the vastus lateralis, which accompany the descending branch of LCFA, are preserved when possible.

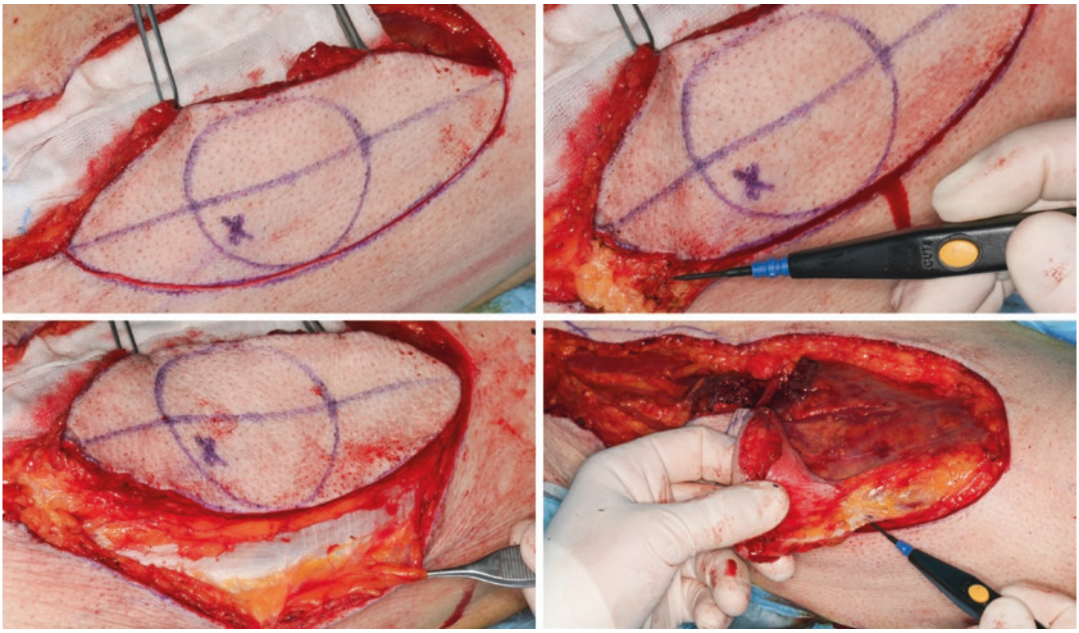

Fig. 8.13 Step 6: Posterior skin incision is performed

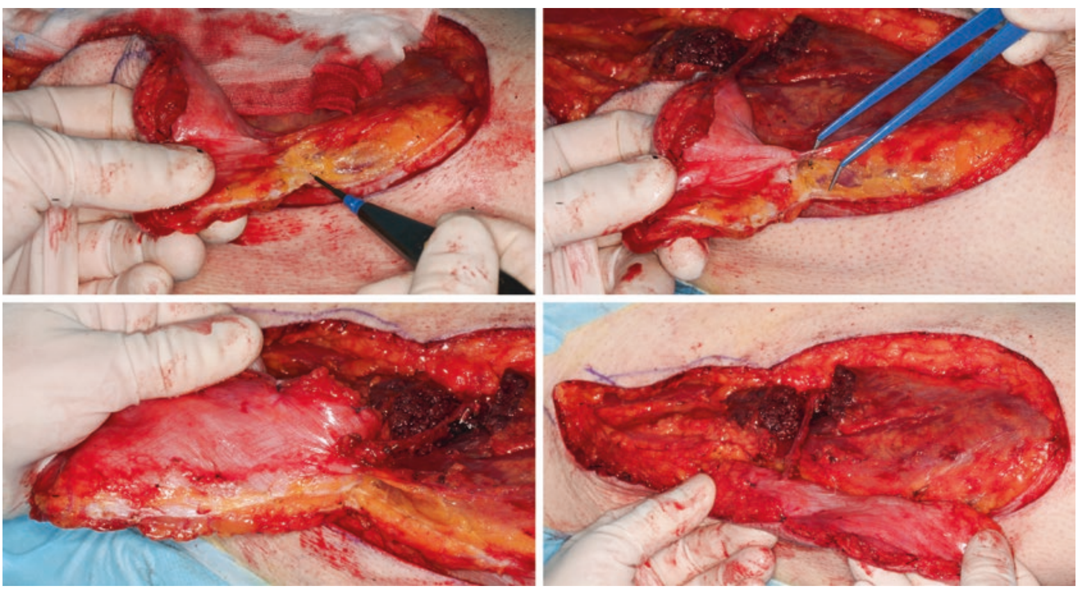

Fig. 8.14 Step 6: Complete release of the flap from the thigh's skin

The exposure of the proximal portion of the descending branch of LCFA and the venae comitantes is achieved by sharp dissection deep between vastus lateralis and rectus femoris, on the surface of the vastus intermedius muscle. The vessels of the flap may be divided at any point along their course to reach the recipient vessels avoiding kinking. Because of its vascular anatomy, the artery and vein can be anastomized in a different side of the neck (Fig. 8.15).

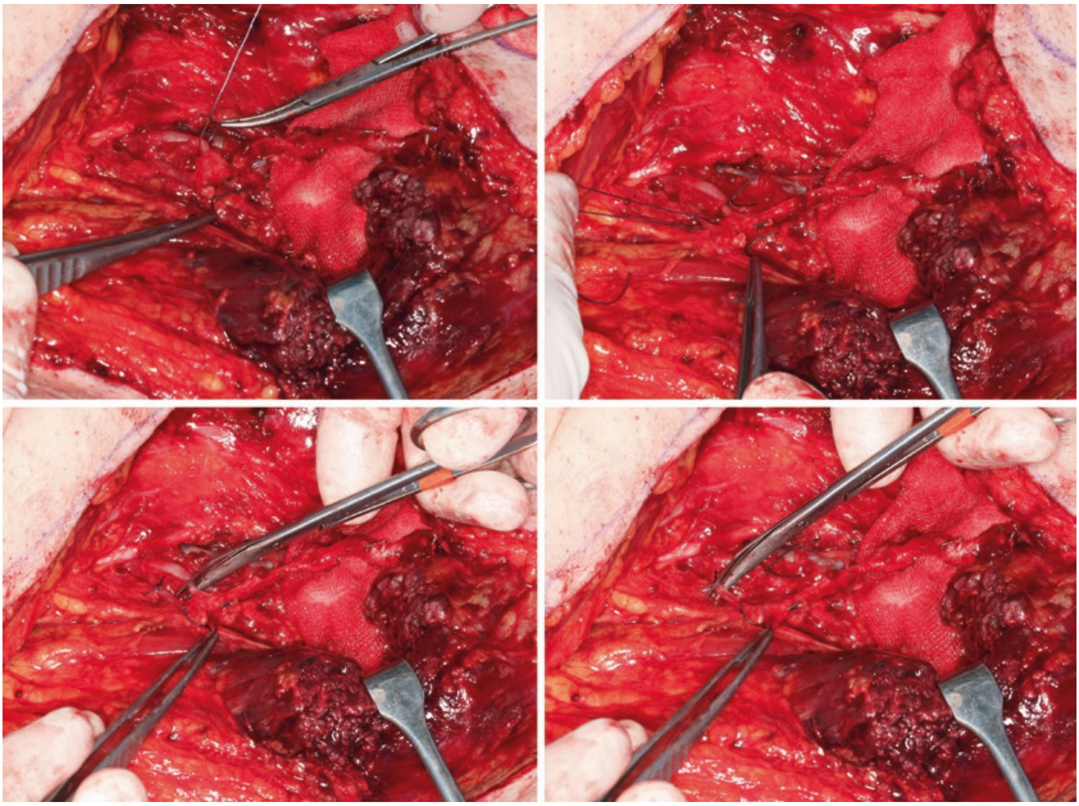

Fig. 8.15 Step 7: Dissection of the pedicle from the deep vessels

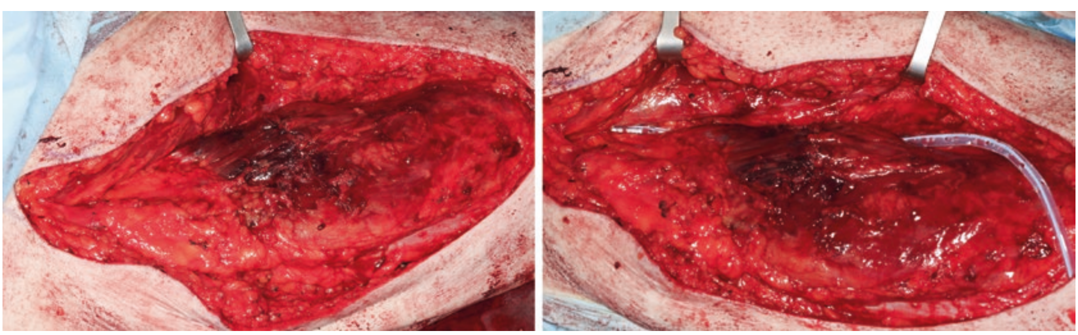

Fig. 8.16 Donor site closure: Muscle is sutured and 1 aspiration drain is positioned

8.5 Donor Site Closure

Checking of hemostasis, reposition of the remaining muscles, and subsequent closure of the donor site are performed. One or two suction drains are placed, and they can be removed after 3 days (Figs. 8.16, 8.17 and 8.18).

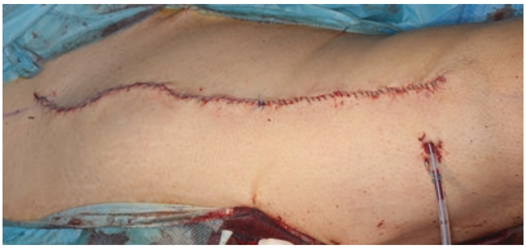

Fig. 8.17 Donor site closure: first intention closure is often possible

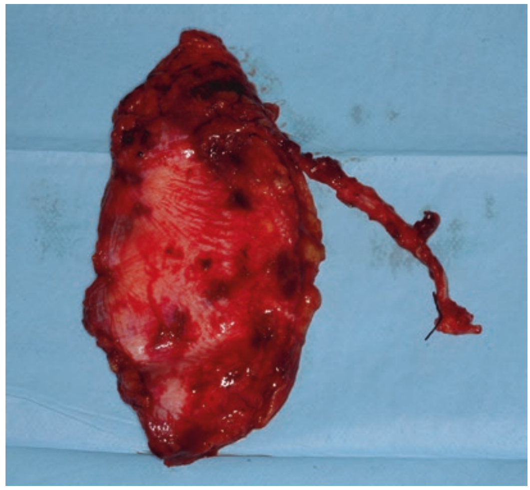

Fig. 8.18 Final appearance of the flap

8.6 Composite Flap

8.6.1 Musculo-Fascio-Cutaneous Thigh Flap

Sometimes, a musculo-fascio-cutaneous flap is necessary if the defect is big and filling of a virtual space is required. To dissect the intramuscular perforator and follow it until the descending branch of LCFA, it is mandatory to identify the entry and exit point of the vessels from the vastus lateralis (Fig. 8.19). Transection of this muscle upstream and downstream avoiding vessel damage guarantees vitality of the deeper muscle layers (Figs. 8.20 and 8.21).

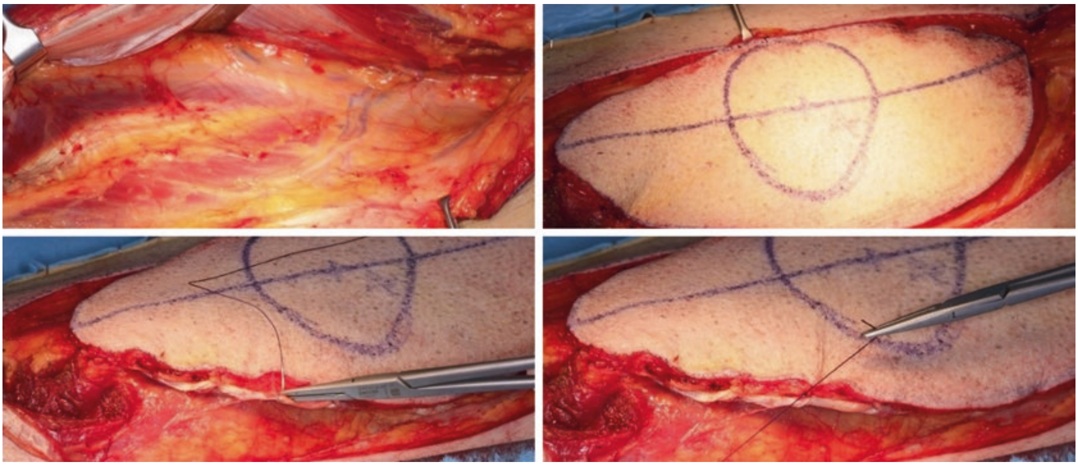

Fig. 8.19 Musculo-Fascio-Cutaneous Thigh Flap: Identification of the pedicle and skin incision

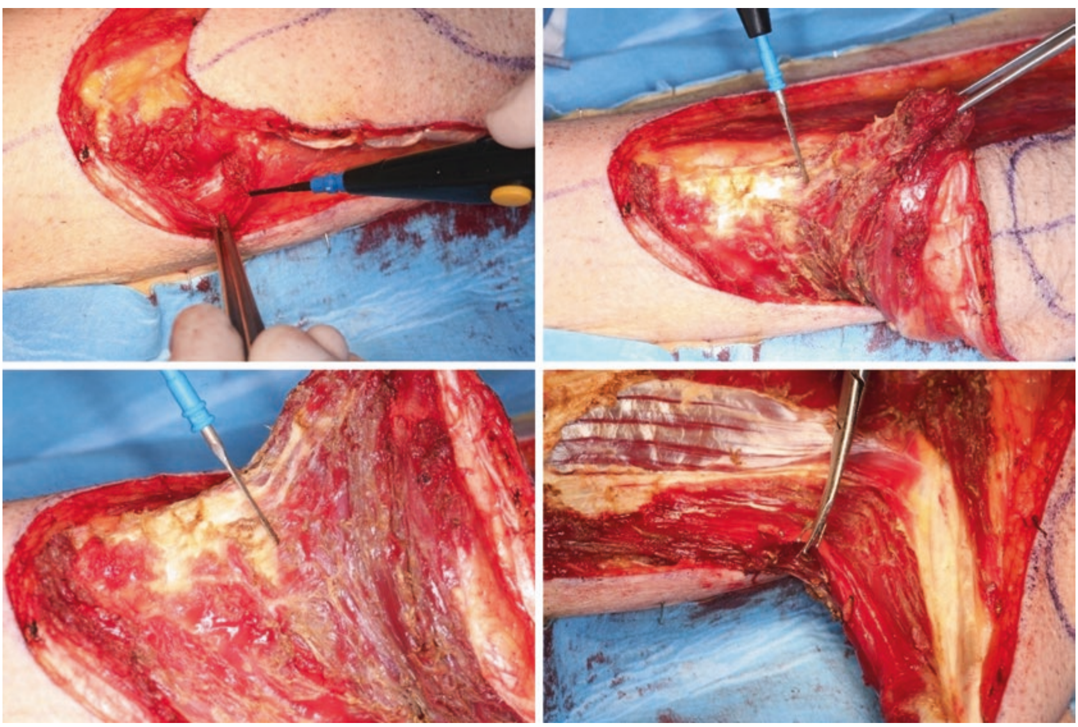

Fig. 8.20 Musculo-Fascio-Cutaneous Thigh Flap: Dissection of the vastus lateralis muscle

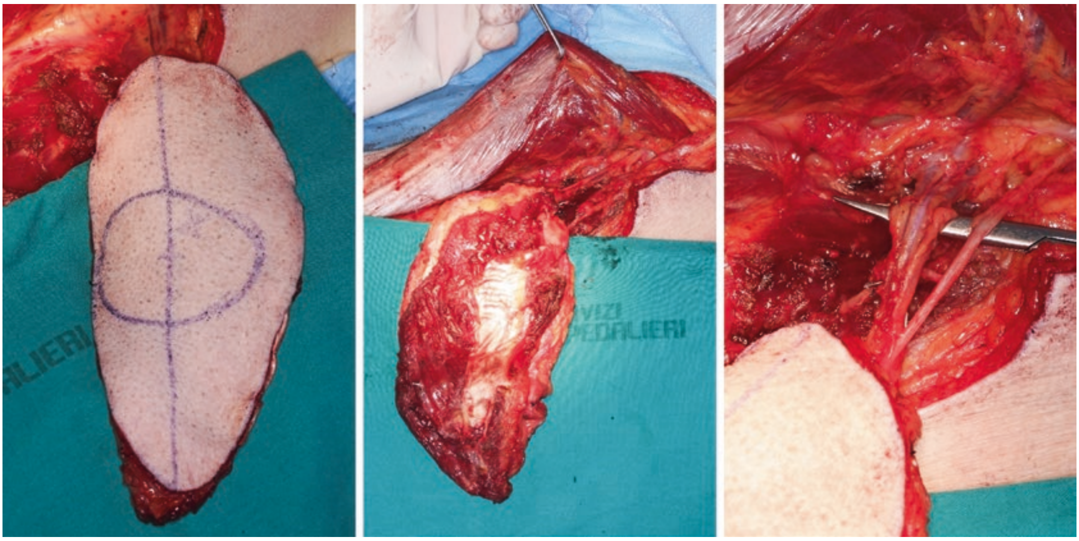

Fig. 8.21 Musculo-Fascio-Cutaneous Thigh Flap: Final apparence of the flap and its padicle

References

1. Yu P. Characteristics of the anterolateral thigh flap in a western population and its application in head and neck reconstruction. Head Neck. 2004;26:759–69.

Further Reading

Wei FC, Jain V, Celik N, Chen HC, Chuang DC, Lin CH. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. Plast Reconstr Surg. 2002;109:2219–26.

Bianchi B, Ferri A, Ferrari S, Copelli C, Boni P, Ferri T, et al. The free anterolateral thigh musculocutaneous flap for head and neck reconstruction: one surgeon's experience in 92 cases. Microsurgery. 2012;32:87–95.

Celik N, Wei FC, Lin CH, et al. Technique and strategy in anterolateral thigh perforator flap surgery, based on an analysis of 15 complete and partial failures in 439 cases. Plast Reconstr Surg. 2002;109:2211–116; discussion 7–8

Cherubino M, Berli J, Turri-Zanoni M, et al. Sandwich fascial anterolateral thigh flap in head and neck reconstruction: evolution or revolution? Plast Reconstr Surg Glob Open. 2017;5:e1197.

9 DIEP Flap in Head and Neck Reconstructions

M. Pignatti, G. Sapino, L. Pacchioni, A. Baccarani, and G. De Santis

9.1 Introduction

Restoration of the aesthetic appearance and function following resection is particularly important in the head and neck.

Traditionally, the radial fasciocutaneous forearm (RFF) flap [1] and the anterolateral thigh (ALT) flap [2] represent nowadays the workhorse for functional reconstruction of this district. However, insufficient tissue thickness and skin availability may limit their use in particularly large resections. Moreover, donor site morbidity (radial artery sacrifice, scarring and tendon exposure in RFF flap; skin graft for larger ALT flaps) must be considered.

First described by Koshima et al. in [3], the deep inferior epigastric perforator (DIEP) flap represents the muscle-sparing evolution of the transverse rectus abdominis muscle flap (TRAM), minimizing the donor site morbidity. Thanks to its characteristics, it has become the gold standard for breast reconstruction since the 1990s [4].

In head and neck reconstruction, the DIEP flap is a reliable and useful alternative when a large skin island or tissue bulk, or both, is required [5–11]. The minimal donor site morbidity (the abdominal wall is not damaged and the scar is easily hidden by the underwear) makes it more appealing than other alternatives (i.e. large ALT, latissimus dorsi flap). Furthermore, even when a thick tissue is not necessary, the DIEP flap can be thinned preserving the perforator, as described by Koshima et al. [12], providing a large skin island.

9.2 Anatomy

The DIEP flap is an adipocutaneous flap from the lower abdomen. It is based on the perforators from the deep inferior epigastric vessels (DIEA and DIEV) (one artery and two comitantes veins), branches of the external iliac artery and vein. The source vessels run extraperitoneally in a cranial direction and then enter the muscle about 3–4 cm caudal to the arcuate line, in the middle third. Two rows of perforators (one medial and one lateral) may be individuated along the muscle course; the majority enters in the middle third of the muscle and is located within 2 cm above and 6 cm below the umbilicus. Several studies have shown that the medial row perforators sprawl a wider territory and may be a more reliable source when a single perforator DIEP flap is harvested. However, Munhoz et al. reported that perforators from the lateral row present a rectilinear course through the muscle, thus facilitating the dissection process [13].

M. Pignatti (✉)
Plastic Surgery, Policlinico di S. Orsola, DIMES, University of Bologna, Bologna, Italy

G. Sapino · L. Pacchioni · A. Baccarani · G. De Santis
Department of Plastic and Reconstructive Surgery, University Hospital of Modena, Modena, Italy

R. Pellini, G. Molteni (eds.), *Free Flaps in Head and Neck Reconstruction*,
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Deep inferior epigastric vessel diameter ranges from 2 to 3.5 mm in size. Pedicle may be variable, but it stands around 10.5 cm in length.

Four perfusion zones have been described by Hartrampf et al. [14] when using an extended transverse skin paddle flap: zone I, which is the most vascularized, lies ipsilateral to the perforator over the rectus; zone III is ipsilateral and lateral to zone I; and zone II and IV are contralateral to the pedicle. Decrease perfusion in zone IV has been described in several studies; thus, this zone should not be included in the flap in order to avoid venous congestion and partial flap necrosis [15]. More recent evaluations of the perfusion zones describe concentric zones from I on the perforator to IV the most external one [16].

The lateral intercostal nerve branches that enter the muscle from lateral provide motor innervation to the rectus muscle. To avoid donor site morbidity as bulging and abdominal wall weakness, these nerves should be preserved during flap harvesting.

9.3 Preoperative Settings

All patients undergo a computed tomographic (CT) angiogram before the surgery, helping to localize the best calibre perforators and to determine their course through the muscle in order to choose the more reliable perforator (on the basis of calibre and position in the skin island) and the one with the shorter course through the muscle (Fig. 9.1a–b).

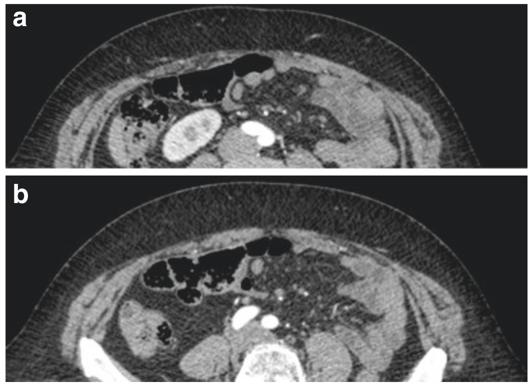

Fig. 9.1 (**a**, **b**) The perforator's course is evaluated with a CTA exam. The "best" perforator should have a short intramuscular portion to facilitate the dissection during surgery

With the patient in a supine position, all suitable perforators from the medial and lateral row are identified with a hand-held Doppler and marked on the abdomen. The superficial inferior epigastric artery (SIEA) and vein (SIEV) are located with the Doppler, when possible, approximately 3–4 cm lateral from the midline on the lower marking of the flap skin island.

The skin paddle can theoretically be oriented in any direction as long as a reliable perforator is included. When an extended transverse skin paddle is required (Fig. 9.2a–c), an elliptical shape design is marked so that the superior border of the flap is drawn approximately at the umbilicus and prolonged laterally toward the anterior superior iliac spines (ASIS). Inferiorly, a line is drawn between the ASIS on the suprapubic crease. The pinch test can be used to make sure the amount of remnant skin is enough for tension-free closure. In most of the cases of breast reconstruction, the skin island has a vertical (craniocaudal distance) height of 11 or 13 cm, while the horizontal (latero-lateral) width is approximately 36 cm. However, when using a DIEP flap for head and neck reconstruction, usually, a smaller flap is sufficient to cover the defect. A lower transverse abdominal design without including the umbilicus or a vertical/oblique-oriented flap (on 1 side of the periumbilical region) may be planned according to perforator location, the patient's lower abdomen characteristics and previous scars and amount of tissue required [5, 6]. In such cases, only the zone I and II and eventually III are included in the flap, thus reducing the risk of venous congestion. When a vertical/oblique flap is planned, the superior and inferior extensions of the markings may cover the entire length of the rectus muscle. This design lacks the cosmetic advantages of the horizontal DIEP skin island where the scar can be hidden by usual clothing. It is therefore rarely indicated, i.e. for small flaps in patients already presenting with an umbilicopubic laparotomy scar.

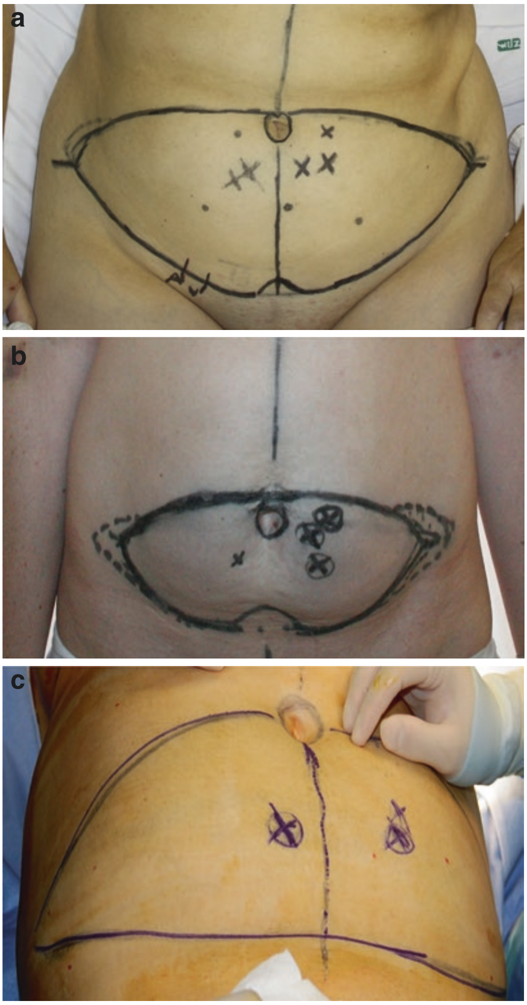

Fig. 9.2 (**a**) Preoperative markings are drawn with the patient in supine position. When a transverse skin paddle flap is chosen, the flap's height should not exceed 13 cm and should include the umbilicus. The periumbilical area frequently has good perforators. The maximum width is usually planned to be approximately 36 cm. Perforators are then located with the hand-held Doppler and marked on the skin. In this case, also, an artery and vein (most probably superficial vessels that should be preserved as explained in the text) were audible at the lower margin of the flap. To facilitate closure of the donor site, an indentation in the marking of the suprapubic incision is created to preserve more skin. (**b**) Another marking is shown in a very thin patient. The best perforators (at CTA and confirmed by Doppler) are marked in the periumbilical area. It is possible to raise a DIEP flap, but the donor site will be less aesthetically pleasing due to the horizontal scar that will not be hidden by clothing. (**c**) After preop prepping, skin markings are repeated. A stapler is positioned on the midline above the umbilicus and on the mons pubis to facilitate the alignment for donor site closure at the end of the operation

9.4 Surgical Technique

The elevation of a DIEP flap should be done under loupe magnification.

According to CTA data and Doppler signal, the preferred perforator is chosen. A change in the plan is possible and even recommended if the clinical appearance of the perforator, when visualized and explored subfascially, is deemed not adequate.

9.4.1 Surgical Steps

1. With a scalpel blade no. 15, the periumbilical incision is made, and using dissection scissors, the umbilical stalk is isolated down to deep fascia (Fig. 9.3).
2. The caudal margin of the flap skin island is then incised to the subdermal layer, cautiously looking for vessels running in caudal-cranial direction in the subcutaneous layer (Fig. 9.4a): the SIEV and in some cases the SIEA can be located and dissected free in a caudal direction for several centimetres and then clipped (Fig. 9.4b, c). The SIEV could be of use at the end of the surgery to provide a venous supercharge in case of venous congestion. In the uncommon case in which a SIEA of acceptable size is found, the surgical plan can be radically changed, and instead of a DIEP flap, a SIEA flap can be used.

   The dissection is deepened down to the deep abdominal fascia of the rectus muscles (Fig. 9.5).
3. The skin incision is prolonged (Fig. 9.6), and the flap is raised starting from the lateral tip of the skin island of the side where the "best" (from the preop evaluation) perforators are located (Figs. 9.7 and 9.8a–b).

   Dissection is carried out in lateral to medial direction using an electrocautery (set on 50 most frequently) to reduce bleeding on the deep fascia plane. The skin and subcutaneous fat are included in the flap; the anterior abdominal fascia and the rectus abdominis muscle are left untouched (Figs. 9.9 and 9.10).

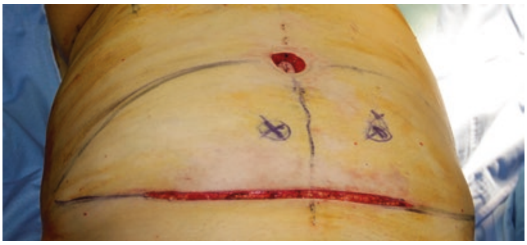

Fig. 9.3 The umbilicus is incised circumferentially and his funicle is isolated down to the deep fascia, as in an abdominoplasty. Flap harvesting begins with the incision at the lower border of the flap in order to localize the SIEA and SIEV

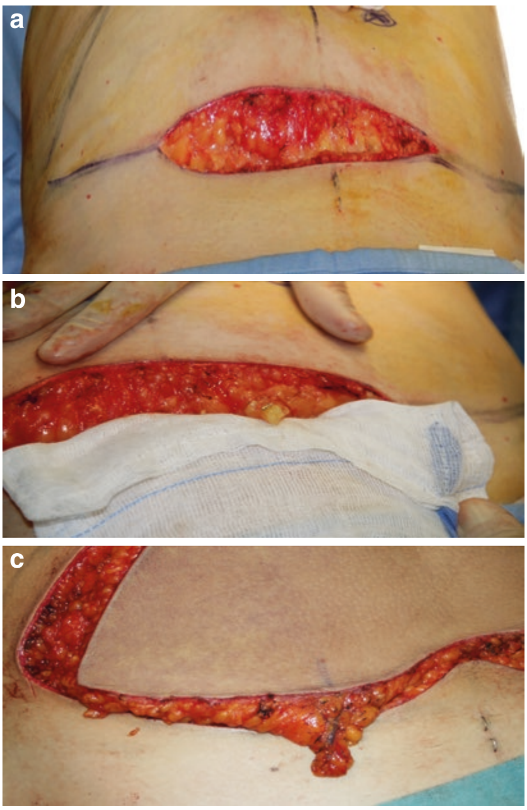

Fig. 9.4 (**a**) A superficial vein has been isolated for a few centimetres and clipped. (**b**, **c**) Once located in the subcutaneous fat, the SIEV is followed in caudal direction for several centimetres and then clipped. The vessel could be used if additional venous drainage is needed at the end of the surgery

4. When the lateral margin of the rectus abdominis is reached, the electrocautery is set to 25 both for cut and coagulation.

Fig. 9.5 Dissection is carried down to deep fascia

Fig. 9.6 The skin incision is prolonged all around the side of the flap where the “chosen” perforator is located

Fig. 9.7 The incision is deepened with the electrocautery down to the external oblique muscle fascia

All the perforators identified from this moment are preserved. The ones of inadequate calibre can be coagulated (Fig. 9.11a–c). The perforator selected from the preoperative investigations as the preferred one should be reached and judged clinically. The final decision on its adequacy requires the visualization of the subfascial calibre.

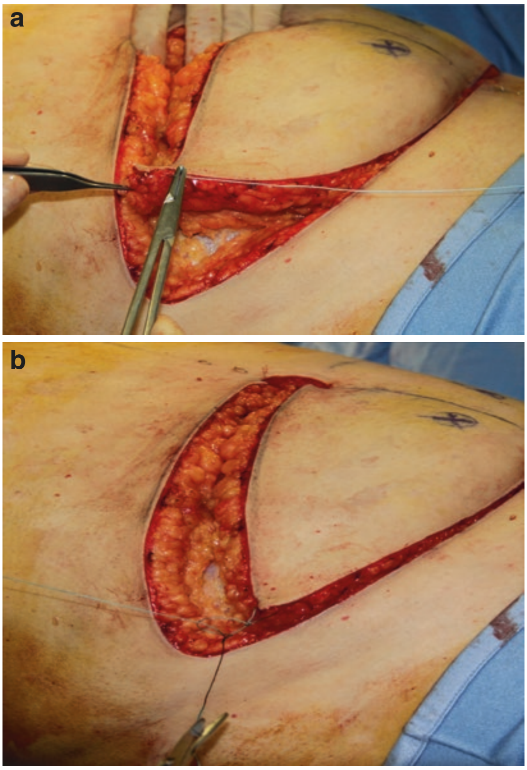

Fig. 9.8 (**a**, **b**) A stitch with a braided suture is placed in the dermis-subcutaneous tissue at the tip of the flap to simplify the flap traction and manipulation during the harvesting

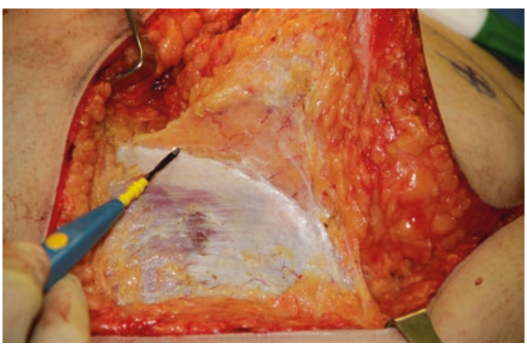

Fig. 9.9 Dissection is carried out in a lateral to medial manner using the electrocautery (set on 50 until the rectus muscle lateral border is reached) alternating coagulation and cut modes

5. Once the main perforator is attained (Fig. 9.12a), the fascia is subsequently incised with a scalpel (Fig. 9.12b, c), the muscle exposed and the vessel visualized (Fig. 9.13).

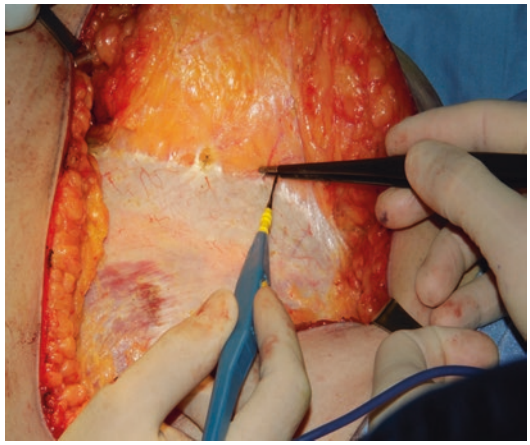

Fig. 9.10 Minor perforators are identified during dissection and carefully cauterized to prevent bleeding

The blunt dissection proceeds with different instruments according to the surgeon's preference.

Our favourite technique uses the bipolar, set on very low settings, to coagulate and at the same time gently spread the muscle fibres along the perforator's course, as no muscle has to be included (Fig. 9.14a). Haemoclips should be used when side branches are encountered. In the unusual case when one perforator is considered to be insufficient to nourish the entire flap, two or three perforators on the same vertical line may be dissected to the point where they join together before entering the deep inferior epigastric artery (DIEA). Although the rules of perforator flap harvesting dictate that no muscle nor fascia should be damaged, there are rare cases when the connection between the muscle fibres, fascia and the perforator is tight. Some surgeons may then consider acceptable to include a small cuff of fascia around the vessel to prevent perforator injuries and spasm during dissection.

Special care must be spent to preserve the motor nerve branches to the rectus muscle to avoid denervation and donor site morbidity.

6. Dissection is continued in the muscle (Figs. 9.15 and 9.16), and lateral branches are

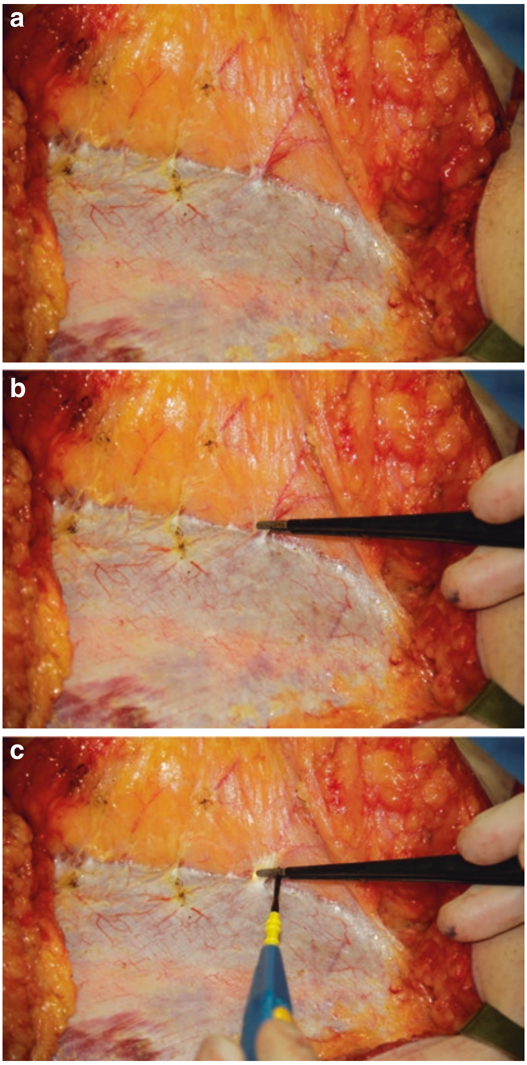

Fig. 9.11 One perforator is preserved and isolated (**a**). Due to the small size and the fact that it was not the best one visualized at the CTA, it is cauterized (**b**, **c**)

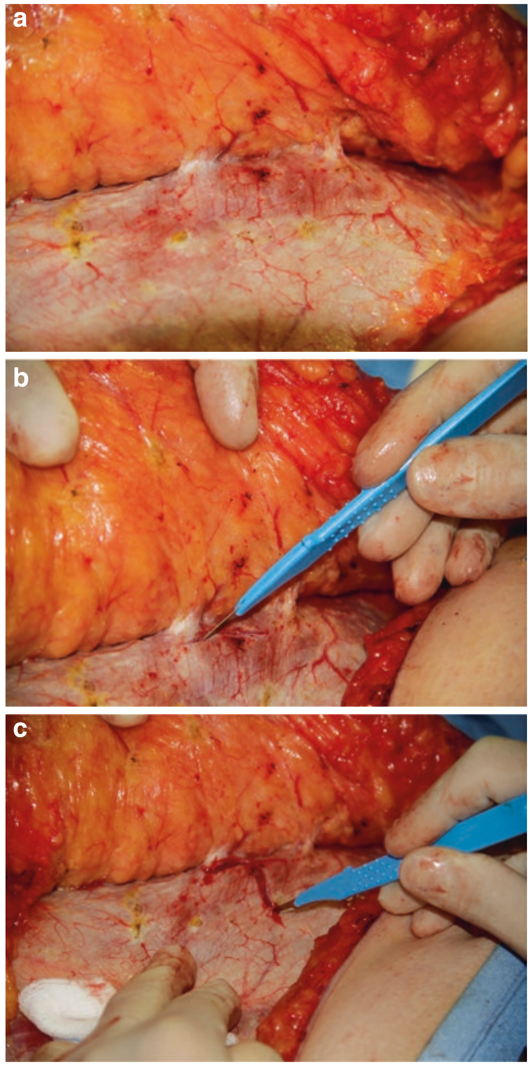

Fig. 9.12 When the "best" perforator is reached (**a**), the fascia is incised with a scalpel exposing the rectus muscle, and the subfascial calibre of the vessels is clinically judged (**b**, **c**)

clipped (Fig. 9.17a, b) until the DIEA and the two DIEV comitantes are located under the rectus muscle (Fig. 9.18), which is elevated with the help of a retractor in order to better visualize the main vessels (Figs. 9.19 and 9.20). They are followed toward their origin until the calibre and the pedicle length are considered adequate for anastomosis. In most of the cases, we prefer to reach the confluence of the two comitantes veins in one vessel to optimize the venous drainage of the flap (Figs. 9.21 and 9.22).

7. Cranially to the perforator, the DIEA and DIEV are clipped.
8. The contralateral abdominal flap is then raised with the same technique used previously, over the deep fascia (Figs. 9.23 and 9.24a, b).

   The best perforators are preserved and temporarily clamped to check that the pedicle already isolated on the contralateral side provides sufficient arterial input and venous drainage (Fig. 9.25).

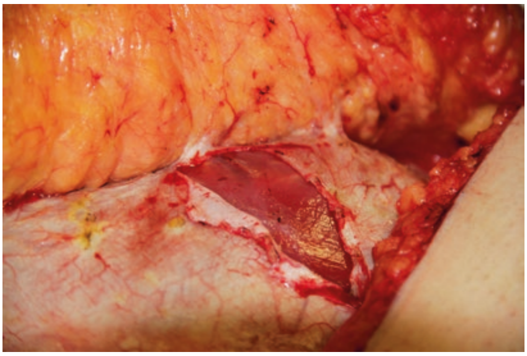

Fig. 9.13 The vessel is seen running within the muscle fibres. When the vessel calibre is considered sufficient by the surgeon, the dissection of the pedicle proceeds in the caudal direction. Special care should be paid not to damage the muscle nor fascia

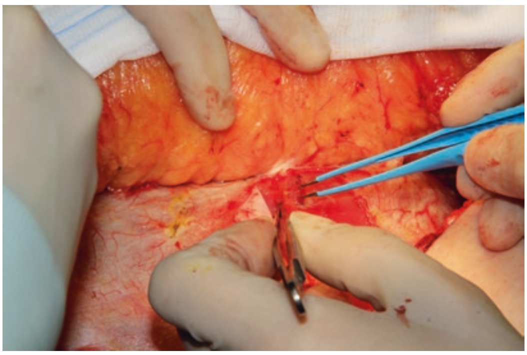

Fig. 9.14 Our favourite technique uses the bipolar, set on very low settings, to coagulate and at the same time gently spread the muscle fibres along the perforator's course, as no muscle has to be included

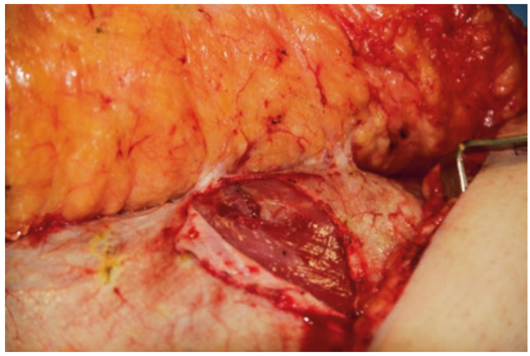

Fig. 9.15 The muscular roof over the pedicle has now been opened

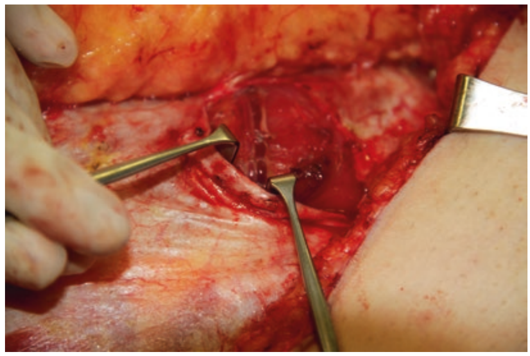

Fig. 9.16 The pedicle is isolated and followed toward the origin of the DIEA-DIEV

9. After 10 min, the colour of the skin island is checked. The border of the perfused area is marked, and the poorly perfused portion is removed.

   The clamped perforators are permanently ligated or clipped (Fig. 9.26).

   The origin of the isolated DIEA-DIEV pedicle is then sectioned, and the flap is free to be re-anastomosed to the recipient vessels.

9.5 Donor Site Management

The anterior fascia sheet is closed using nonabsorbable sutures in an interrupted or continuous manner (Fig. 9.27a, b).

The superior abdominal flap is undermined above the fascia to the costal border and advanced caudally to the inferior border of the incision. Baroudi stitches may be used to loosen tension, reduce the dead space and facilitate the skin closure.

Like it is done in an abdominoplasty, an oval skin excision is done on the midline of the abdominal flap above the umbilical stalk, and the umbilicus is pulled out and sutured on its new position (Fig. 9.28a, b).

Possible specific complications of the donor site are bulging (area of reduced strength and contractility of the rectus muscle) or, very rarely if the rectus muscle is spared, hernia.

A meticulous dissection and preservation of the muscle and motor nerves and a resistant suture of the fascia are needed to prevent these complications.

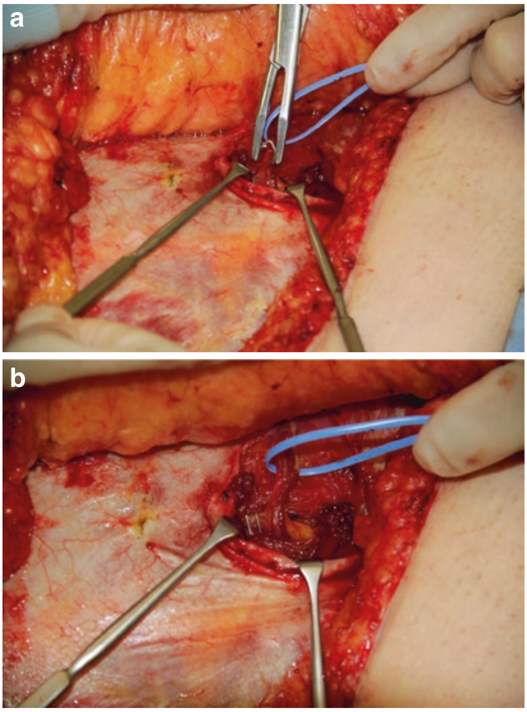

Fig. 9.17 (**a**, **b**) Haemoclips of various dimensions should be used when side branches are encountered. Cauterization of these branches has the risk of pedicle damage due to direct cauterization or due to the heat wave

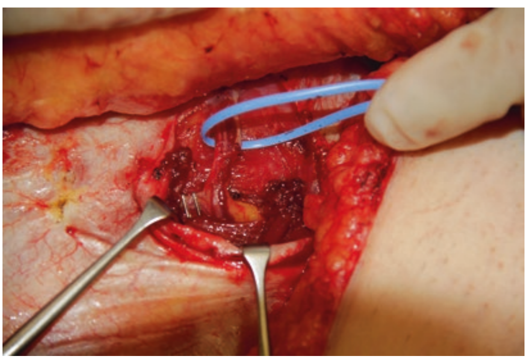

Fig. 9.18 Dissection proceeds following the perforator vessels under the rectus muscle, where the DIE vessels are encountered

9.6 Postoperative Care

Abdominal bindings are positioned at the end of the surgery and should be used for several weeks.

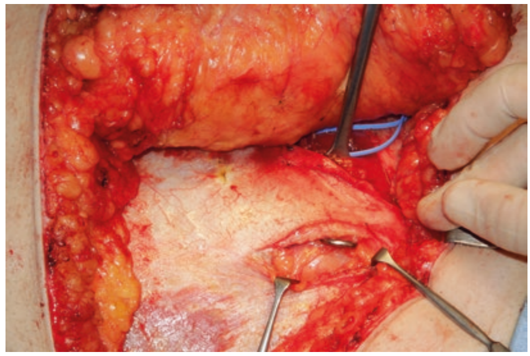

Fig. 9.19 Depending on the DIEA-DIEV course and branching, a second fascia incision laterally to the lateral margin of the rectus muscle might be useful. The vessels are located in the abundant fatty tissue and followed cranially toward the pedicle already isolated

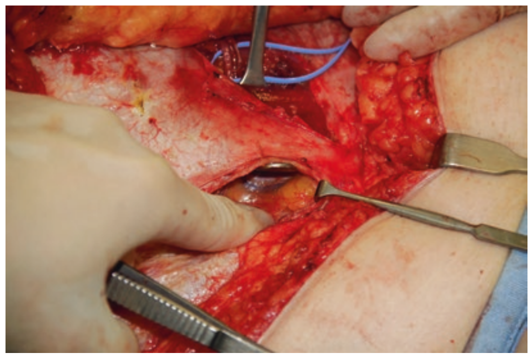

Fig. 9.20 The largest retractor is positioned under the right rectus muscle, on top of the vessels (DIEA-DIEV), while a vessel loop is placed around the perforator

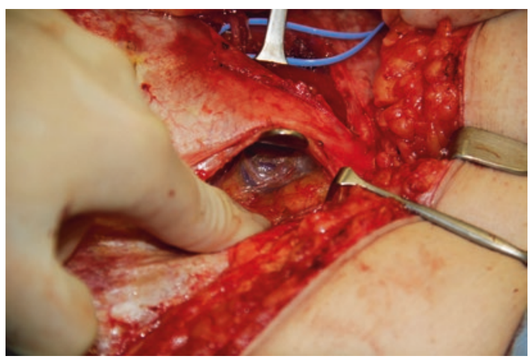

Fig. 9.21 DIEA and DIEV are followed in a caudal direction, until their calibre and length is considered adequate for anastomosis

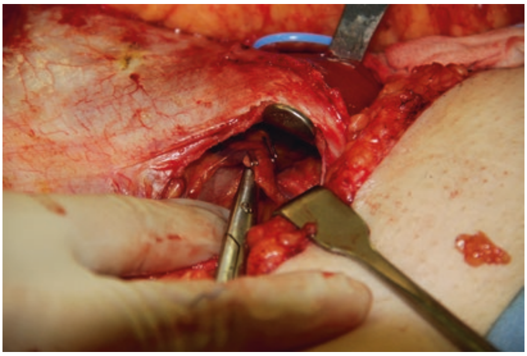

Fig. 9.22 Haemoclips of various dimensions have been positioned to close side branches (circle): in this case, the lateral branch of the DIEA, being the medial branch the flap pedicle

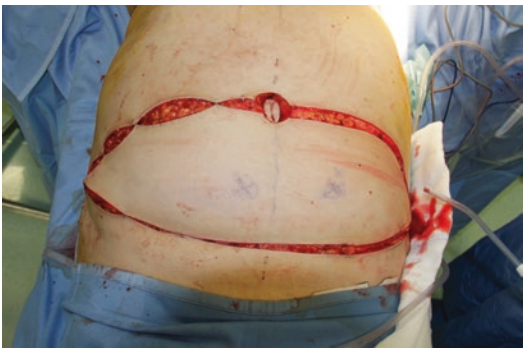

Fig. 9.23 The contralateral flap is incised and raised as previously shown

After the procedure, the patient is usually transferred to the intensive care unit for strict monitoring during the first night. Colour, capillary refill, temperature, turgor and Doppler signal help the surgeon in monitoring the free flap course. The patient is usually positioned in a chair from the first postoperative day, depending on the entity of the demolitive part of the surgery.

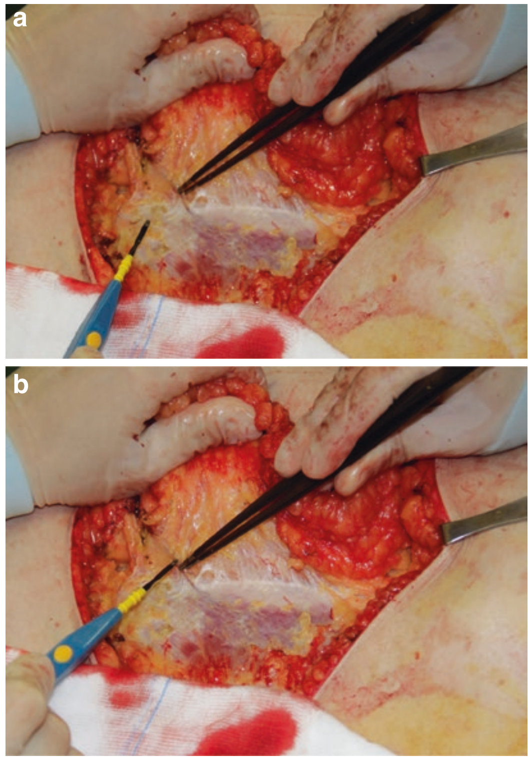

Fig. 9.24 (**a**, **b**) Dissection proceeds in the same suprafascial plane; minor perforators are cauterized when encountered

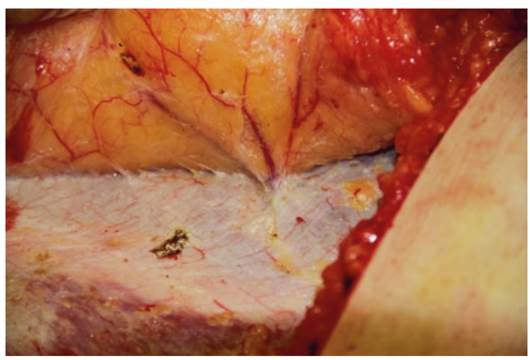

Fig. 9.25 When the lateral margin of the rectus muscle is crossed, all perforators are identified and evaluated by the surgeon. Those vessels are then clamped to check if the selected pedicle on the contralateral side can provide the required blood supply to the flap

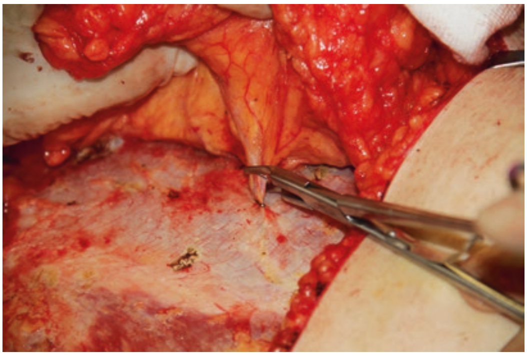

Fig. 9.26 When the surgeon is sure about the reliability of the contralateral pedicle, all the perforators of the contralateral flap are clipped

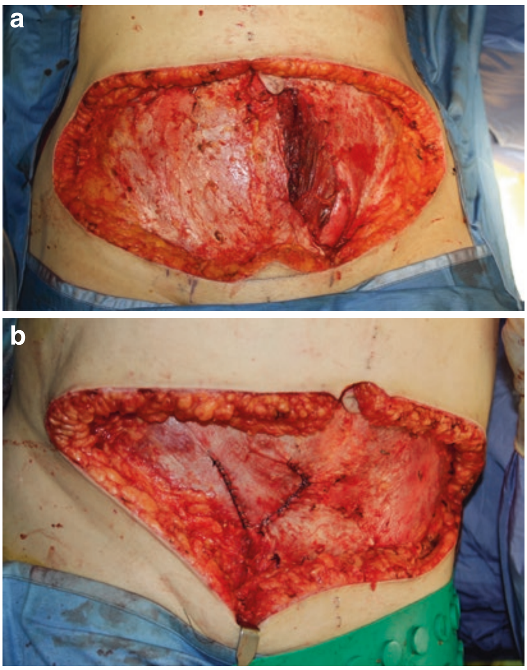

Fig. 9.27 (**a**) Intraoperative picture of different patients showing the donor site appearance when the DIEP flap has been transposed to the recipient site. Note the exposure of the rectus abdominis fibres through the fascia incision. (**b**) Abdominal fascia closure using nonabsorbable suture

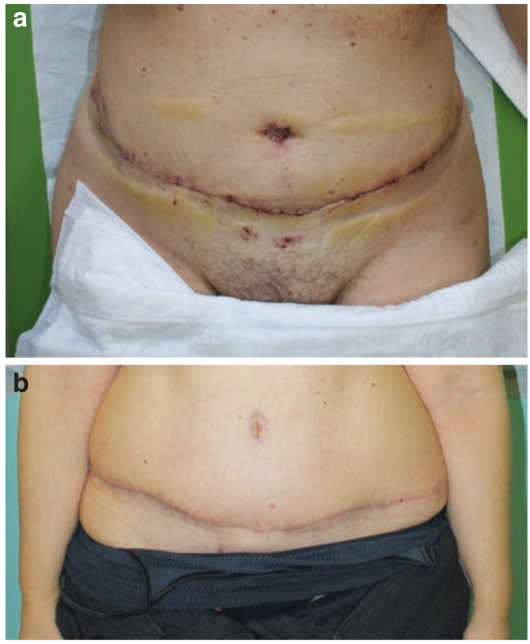

Fig. 9.28 (**a**) Postoperative appearance of the donor site 7 days postop and (**b**) at 1-year follow-up

References

1. Song R, Gao Y, Song Y, Yu Y, Song Y. The forearm flap. Clin Plast Surg. 1982;9(1):21–6.
2. Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. Br J Plast Surg. 1984;37(2):149–59.
3. Koshima I, Soeda S. Inferior epigastric artery skin flaps without rectus abdominis muscle. Br J Plast Surg. 1989;42(6):645–8.
4. Allen RJ, Treece P. Deep inferior epigastric perforator flap for breast reconstruction. Ann Plast Surg. 1994;32(1):32–8.
5. Clemens MW, Davison SP. Buried deep inferior epigastric perforator flaps for complex head and neck contour defects. J Reconstr Microsurg. 2009;25(2):81–8. https://doi.org/10.1055/s-0028-1090601. Epub 2008 Oct 15
6. Beausang ES, McKay D, Brown DH, Irish JC, Gilbert R, Gullane PJ, Lipa JE, Neligan PC. Deep inferior epigastric artery perforator flaps in head and neck reconstruction. Ann Plast Surg. 2003;51(6):561–3.
7. López-Arcas JM, Arias J, Morán MJ, Navarro I, Pingarrón L, Chamorro M, Burgueño M. The deep inferior epigastric artery perforator (DIEAP) flap for total glossectomy reconstruction. J Oral Maxillofac Surg. 2012;70(3):740–7. https://doi.org/10.1016/j.joms.2011.02.098. Epub 2011 Jul 29
8. Woodworth BA, Gillespie MB, Day T, Kline RM. Muscle-sparing abdominal free flaps in head and neck reconstruction. Head Neck. 2006;28(9):802–7.
9. Louie O, Dickinson B, Granzow J, Boyd JB. Reconstruction of total laryngopharyngectomy defects with deep inferior epigastric perforator-flaps. J Reconstr Microsurg. 2009;25(9):555–8. https://doi.org/10.1055/s-0029-1236833. Epub 2009 Aug 20

10. Yano T, Sakuraba M, Asano T, Sarukawa S. Head and neck reconstruction with the deep inferior epigastric perforator flap: a report of twocases. Microsurgery. 2009;29(4):287–92. https://doi.org/10.1002/micr.20617.
11. Koshima I, Nanba Y, Tsutsui T, Takahashi Y, Watanabe A, Ishii R. Free perforator flap for the treatment of defects after resection of huge arteriovenous malformations in the head and neck regions. Ann Plast Surg. 2003;51(2):194–9.
12. Koshima I, Moriguchi T, Soeda S, Tanaka H, Umeda N. Free thin paraumbilical perforator-based flaps. Ann Plast Surg. 1992;29(1):12–7.
13. Munhoz AM, Ishida LH, Sturtz GP, Cunha MS, Montag E, Saito FL, Gemperli R, Ferreira MC. Importance of lateral row perforator vessels in deep inferior epigastric perforator flap harvesting. Plast Reconstr Surg. 2004;113(2):517–24.
14. Hartrampf CR, Scheflan M, Black PW. Breast reconstruction with a transverse abdominal island flap. Plast Reconstr Surg. 1982;69(2):216–25.
15. Holm C, Mayr M, Höfter E, Ninkovic M. Perfusion zones of the DIEP flap revisited: a clinical study. Plast Reconstr Surg. 2006;117(1):37–43.
16. Saint-Cyr M, Wong C, Schaverien M, Mojallal A, Rohrich RJ. The perforasome theory: vascular anatomy and clinical implications. Plast Reconstr Surg. 2009;124(5):1529–44. https://doi.org/10.1097/PRS.0b013e3181b98a6c.

Part IV

Bone Flaps

Subscapular System

10

G. Molteni, M. Ghirelli, J. Zocchi, and R. Pellini

10.1 Anatomy

Scapular region is on the superior posterior surface of the trunk and is defined by the muscles that attach to the scapula. These muscles can be divided into extrinsic muscles, which join the axial to the appendicular skeleton (trapezius, latissimus dorsi, levator scapulae, rhomboid minor, and rhomboid major), and intrinsic muscles, which join the scapula to the humerus (deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis). Scapula is a flat triangular bone which consists of a costal (anterior) surface, a dorsal (posterior) surface, and three borders, superior, medial (vertebral), and lateral (axillary). The lowest point is the inferior angle, defined as the tip of the scapula, while a transverse process, the spine of the scapula, divides the posterior surface in a supraspinous fossa above and a larger infraspinous fossa below. Blood is brought to the scapular region by a network of arteries, which form the scapular anastomosis: muscles medial and superior to the scapula receive blood from the dorsal scapular, transverse cervical, and suprascapular arteries, which are branches of the subclavian artery, and also from the acromial artery, which is a branch of the axillary artery; muscles anterior and lateral to the scapula are supplied by the subscapular and posterior circumflex humeral arteries, which are derived from the axillary artery. The extensive arterial anastomosis at the scapular region provides a collateral circulation, so if one vessel is blocked or damaged, many others can provide blood to the region.

The anatomy and in particular the peculiar vascularization of this region led to the evolution in the last decades of the so-called subscapular system flaps (SSSF). Subscapular artery is a branch of axillary artery that, through the circumflex scapular artery (CSA), supplies two large cutaneous flaps in addition to the lateral scapula itself and, through the thoracodorsal artery (TDA), provides vascularization to the latissimus dorsi muscle and its overlying skin, with angular and serratus branches to the scapular tip and serratus muscle, respectively. This particular vascular anatomy, based on a single pedicle but with the possibility to exploit gradually its branches, allows the harvesting of chimeric free flaps: at the same time, taking advantage

G. Molteni
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

M. Ghirelli (✉)
Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital of Modena, Modena, Italy

J. Zocchi · R. Pellini
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

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of the different independent branches originating from the subscapular artery and its two major branches, this system guarantees the mobility of the various flap to each other. Both these two anatomo-functional aspects make subscapular flap a valuable alternative in cases of complex three-dimensional defects that include both osseous and soft tissue components, as well as more than one epithelial surface (e.g., mucosa and skin). As a consequence, from the 1980s, a wide variety of variations of the subscapular flap have been described: scapular fasciocutaneous, parascapular fasciocutaneous, scapular-parascapular osteofasciocutaneous, latissimus dorsi, latissimus dorsi fasciocutaneous, latissimus dorsi rib osteomusculocutaneous, serratus anterior, serratus anterior musculocutaneous, and serratus anterior rib [1]. Combination of different tissue flaps into single chimeric flap has also been widely explored. Basing on the anatomical study by Saijo in 1978 [2], expanded later by Dos Santos [3], the first to report a clinical use of subscapular flap was Gilbert [4]: this was a fasciocutaneous flap, nourished by a transverse septocutaneous branch from the circumflex scapular artery. As a variation, a parascapular flap, designed along the lateral border of the scapula and based on the descending septocutaneous branch of the circumflex scapular artery, was described in 1982 by Nassif [5]. The next evolution brought to harvest an osteocutaneous flap including the lateral border of the scapula [6], while a further development followed the finding that the caudal part of the lateral border (the tip of the scapula) had a different vascularization [7], derived by the angular branch of the thoracodorsal artery. This discovery leads to important clinical consequences enabling the harvesting of two separate bony segments based on two separate branches of the subscapular artery.

10.1.1 Neurovascular Anatomy

The subscapular artery and vein constitute the nourishing vessels of the SSSF. These vessels arise from the posterior aspect of the third part of the axillary artery and vein. Very few variations about the origin and the course of the subscapular artery have been reported: in the study by Roswell et al., in a series of 100 cadaver dissection, it arose from the third part of the axillary artery in 81% of cases, from the second part in 13%, and from the first part or was absent in 6% [8]. In the same study, the average diameter of the vessel resulted of 6 mm, representing the largest branch of the axillary artery. The artery follows the inferior margin of the subscapularis muscle, and 2.2 cm (range 2–3 cm) after its origin, before entering the triangular space, it divides in two principal branches: the circumflex scapular artery (CSA) and the thoracodorsal artery (TDA). Triangular space is an area bordered laterally by the long head of the triceps brachii, inferiorly by the teres major, and superiorly by the teres minor muscle: at this level, CSA has an average diameter of 4 mm [8] and runs with its two venae comitantes (2.5–4 mm) in the fascial septum between the teres major and minor, giving muscular branches to these muscles and periosteal branches to the lateral border of the scapula, before terminating in the descending and transverse cutaneous branches, nourishing vessels for the scapular(or subscapular) and parascapular fasciocutaneous flaps. It can reach a length of 7–10 cm [9] and up to 11–14 cm if harvested with the subscapular artery. While CSA takes its origin from the subscapular artery, the two CSV in the majority of cases drain in the thoracodorsal vein or directly in the axillary vein in 10% of cases [10]. Thoracodorsal artery is the other main branch of subscapular artery. A variation in its origin as a direct branch of the axillary artery is reported in 3% of cases [11]; it has a mean length between origin and muscular hilum of 9.3 cm (range 6–16.5 cm) and an average diameter of 2.7 mm at its origin, while its accompanying vein is 3.4 mm [12]; it gives origin to the angular branch that supplies the scapular tip: this branch starts just proximal to the serratus anterior muscle in 58% of cases, while in the remaining 42% it arises from the crossing branch from the TDA to the serratus anterior [13]. Other studies report a rarer lower origin: from the anterior serratus branch and from the TDA inferior to the origin of anterior serratus branch [14], or additionally, the presence of two different arteries supplying the scapular tip, usually one coming from the proximal portion of the TDA and the other from the serratus anterior branch or both deriving from this latter muscular branch [15], has been described. The angular branch, traveling between the serratus, subscapular, and teres major muscle, spreads out small feeders to these muscles [7], before giving its terminal branches to the scapular periosteum at a point about 3 cm cephalad to the inferior scapular border [10]. Piazza reports that the most reliable anatomical landmark by which the angular branch can be identified is the loose areolar tissue overlying the serratus anterior (or beneath the fascia of such a muscle) between the teres major and the latissimus dorsi, in close proximity (2–3 cm) to the lateral aspect of the tip of the scapula [16]. The distance between the bony supply entry point of the angular branch and that of the circumflex scapular artery is estimated to be from 6 to 9 cm [16]. There is no consensus in the literature on the amount of bone that can be safely harvested using the angular branch: some authors suggest limiting the bone length to 6 cm [14], and others include the distal portion of the scapular lateral margin, increasing the bone length to up to 14 cm [17]. Mean combined pedicle length of the angular branch and thoracodorsal artery is 14.8 cm, which can grow up to 16.7 cm when the subscapular artery is included [15].

10.2 Subscapular System Chimeric Flap: Surgical Option

As already mentioned, the peculiar vascular anatomy of SSSF provides the ability to design a “chimeric flap” which is a combination of regional flaps that all converge to a single pedicle. Combinations of the skin, fascia, bone, and muscle can be harvested in a single flap. The long separation between the circumflex and thoracodorsal branches allows for generous mobility and spatial independence between the different tissue components allowing for its use in complex three-dimensional reconstruction. The most reported and utilized chimeric flap is probably the one including latissimus dorsi flap that provides a large amount of muscular and cutaneous tissue, harvested with a scapular tip bony flap [17, 18], but other combinations, differently comprehending the skin (latissimus dorsi, subscapular, parascapular flap), soft tissue components (muscle provided by latissimus dorsi, serratus anterior, or teres major muscle), and osseous components (scapular tip or later border of scapular bone), can be designed [13, 19, 20].

10.3 Thoracodorsal Artery Chimeric Flap Harvesting

10.3.1 Patient Positioning

Position of the patient is studied to avoid position changing during surgery, and when needed, a contemporary double equipped surgery is allowed. Correct patient positioning is one of the most important issue in a good scapula chimeric flap harvesting.

The basin pelvis and the trunk are rotated 30°. This position could be maintained with specific pneumatic sack or tissue roll. The correct position is obtained when all skin landmarks are visible.

Position of the superior arm is crucial for an optimal flap harvesting. The superior arm has to be free for movements, so it is included in the surgical field. The arm is put over the trunk and is sustained in a triangular fashion using tissue roll. When it is necessary, the assistant surgeon moves the arm to help the first surgeon during the surgical procedure (Fig. 10.1).

10.3.2 Flap Design

The main surgical landmarks are the scapula especially the tip and the lateral board, the anterior superior iliac spine, and finally the midaxillary line. The first step is to draw a line which connects the midpoint of the axilla and a point midway between the anterior superior iliac spine

Fig. 10.1 Anatomical landmark identification and patient positioning

Fig. 10.2 Anatomical landmark identification with lat dorsi flap

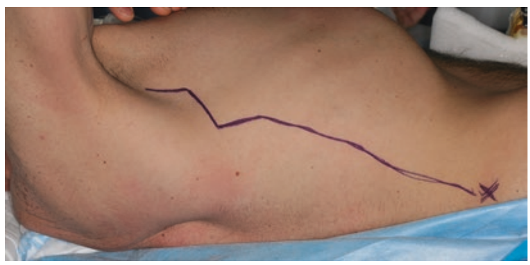

Fig. 10.3 Anatomical landmark identification without skin paddle

and the posterior superior iliac spine on the iliac crest. This line corresponds to the latissimus dorsi line. Further steps depend on the type of flap required for the reconstruction. Skin paddles may be drawn on the skin depending on the surgical plan; multiple skin paddles can be harvested on the latissimus dorsi, anterior serratus, and scapular and parascapular flaps (Fig. 10.2a). Latissimus dorsi skin flap is drawn at the proximal or middle third of the line, because in this area perforating vessels that supply the skin are more numerous and reliable (Fig. 10.2a, b).

When no skin paddle is needed, incision line is draw from midpoint of axilla and midpoint between anterior superior iliac spine and posterior superior iliac spine on the iliac crest (Fig. 10.3).

10.3.3 Step 1: Skin Incision

The skin incision and the flap design depend on the type of flap that will be harvested. In case of latissimus dorsi component, the incision is performed along the anterior margin of latissimus dorsi flap. The upper part of the incision can be S shape for a less tension closure at the end of flap harvesting. When it is not necessary, the incision follows the line previously outlined. The depth of the incision reaches the latissimus dorsi muscle and its fascia (Fig. 10.4).

In the downward part, the latissimus dorsi muscle fibers and the serratus anterior muscle fibers are positioned almost perpendicular (Fig. 10.5, red arrow). The first is on a deeper plane than the latter. The skin and subcutaneous tissue located at the superior boarder should be anchored with some hooks or skin stitches.

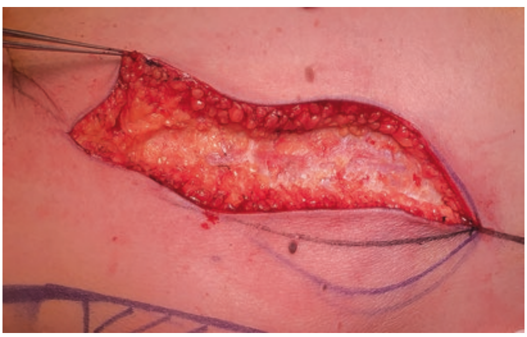

Fig. 10.4 Step 1: Skin incision

10.3.4 Step 2: Identification of Subscapular Vascular System

The connective tissue between latissimus dorsi and anterior serratus muscle contains the subscapular vascular system and its branches. The dissection of this space must be performed accurately, to allow the identification of all parts of the vascular system. The artery that supplies the anterior serratus muscle usually is the first to be visible. It goes along the muscle in contact to it (Fig. 10.6 red arrow). Artery that feeds the latissimus dorsi muscle normally starts in the posterior portion of the pedicle entering the muscle in its proximal third.

These two arteries are normally the terminal ones. The surgeon, usually, follows one of these braches to reach thoracodorsal trunk. Subsequently, it is possible to identify the other branches, the angular artery and the circumflex artery (Fig. 10.7).

The circumflex artery is shown in Fig. 10.8 (yellow arrow). This artery is normally the first branch of thoracodorsal artery that origins from the axillary artery (red arrow) located near its vein (blue arrow).

The angular artery starts normally deeper than the other ones, but there is a great variability in its origin. For this reason, it is more difficult to identify it.

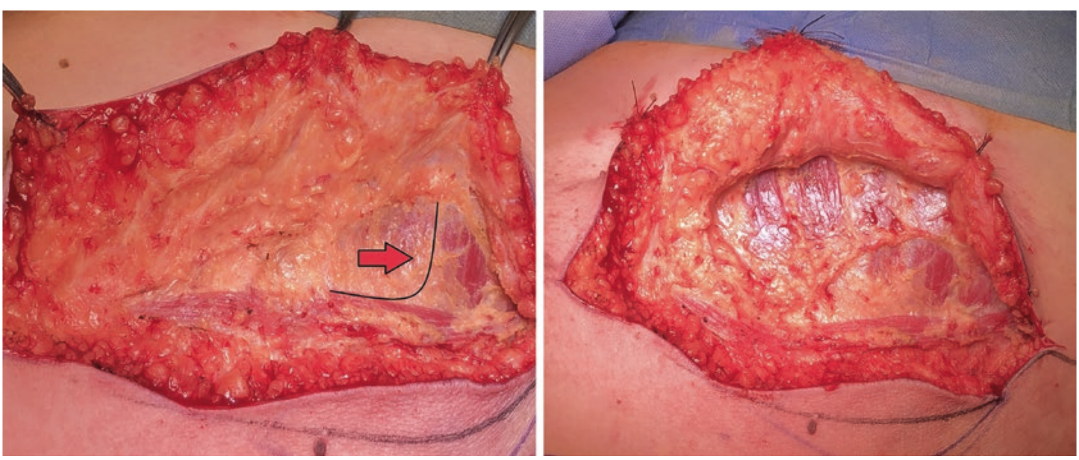

Fig. 10.5 Step 1: anterior skin flap elevation; lat dorsi and anterior serratus muscles identification

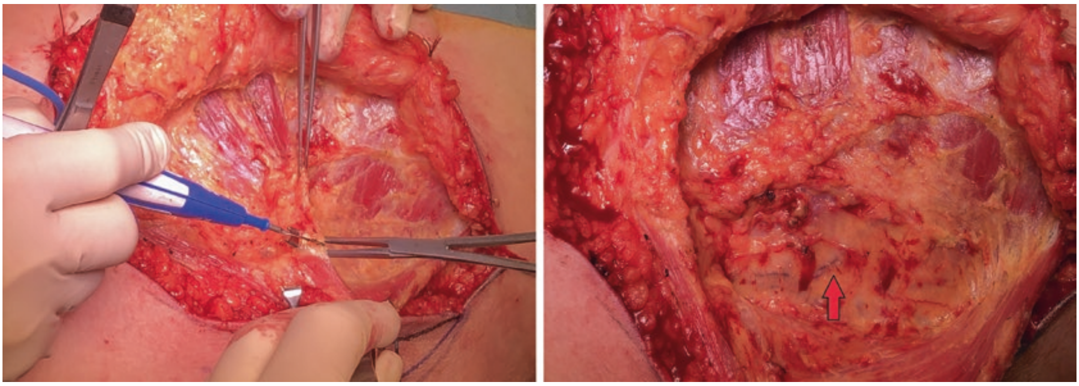

Fig. 10.6 Step 2: identification of anterior serratus branch of the pedicle (red arrow)

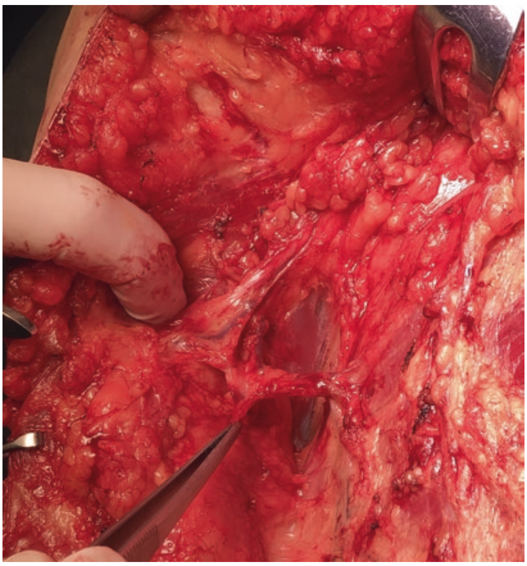

Fig. 10.7 Step 2: main pedicle is identify

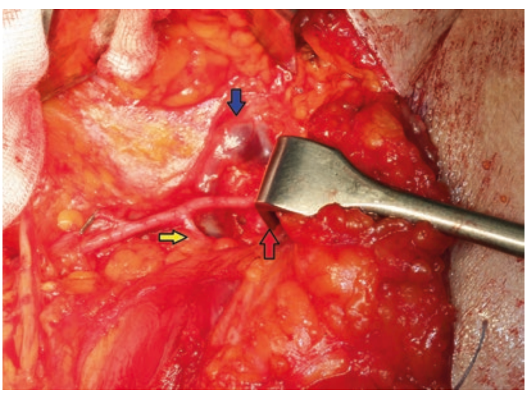

Fig. 10.8 Step 2: anatomy of the subscapular system is shown: circumflex artery (yellow arrow); axillary vein (blue arrow) and artery (red arrow)

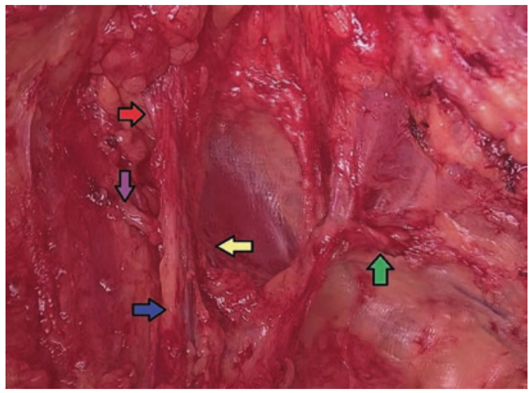

Fig. 10.9 Step 2: Subscapular vascular system

Figure 10.9 shows the subscapular vascular system (green arrow, anterior serratus artery; yellow arrow, angular artery; blue arrow, latissimus dorsi artery; violet arrow, circumflex artery; and red arrow, subscapular artery).

The subsequent steps are based on the type of flap that is necessary.

10.3.5 Step 3: Latissimus Dorsi Flap Harvesting

When the vascular pedicle of the latissimus dorsi is identified (Fig. 10.10 red arrows, Fig. 10.11 right arrow), the projection of the artery is sign on the skin. A more precise skin flap is designed, depending on the surgical defect. Skin island dimensions can be up to 20 cm width (maximum to close primarily

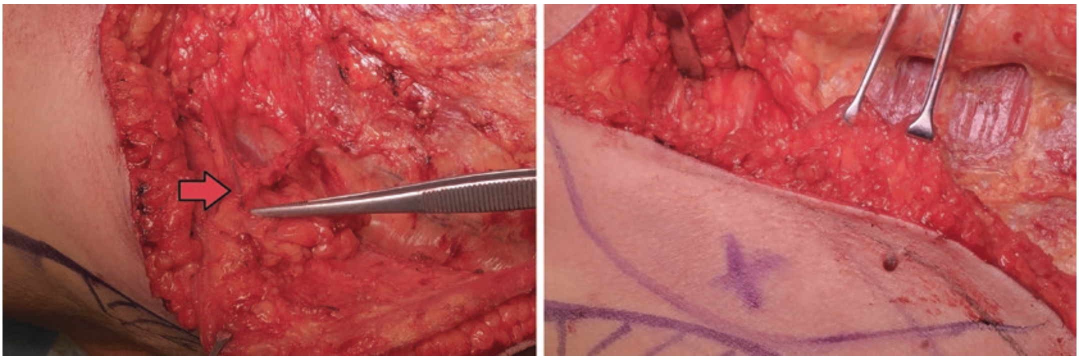

Fig. 10.10 Step 3: latissimus dorsi flap harvesting

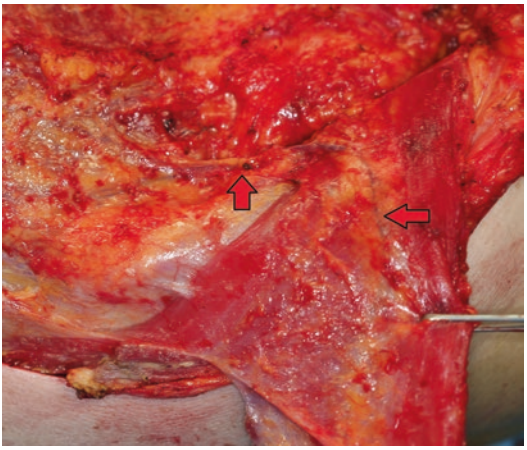

Fig. 10.11 Step 3: latissimus dorsi pedicle

8–10 cm), and 30 cm length in dimension can be harvested (Fig. 10.10).

At this time, posterior skin incision and resection of the muscle from downward to upward are performed. Keep in mind the position of the angular artery (Fig. 10.12 yellow arrow) and the latissimus dorsi one.

The cranial portion of the muscle (muscle insertion) is very thick, so the dissection could be performed layer by layer (Fig. 10.13).

At the end, the latissimus dorsi flap is positioned anteriorly, to better visualize vascular pedicle and its branches (Fig. 10.14).

10.3.6 Step 4: The Anterior Serratus Flap Harvesting

The anterior serratus flap can be harvested in only muscular component or the skin and muscle. Usually, the last three caudal muscle portions are harvested (Fig. 10.15a).

The flap is detached from the ribs. During this step, attention must be paid not to damage pleura. The artery is carefully dissected until the confluence with thoracodorsal truck (Fig. 10.15b, c yellow arrows).

10.3.7 Step 5: Scapula Harvesting

Scapula is dissected posteriorly and inferiorly from the latissimus dorsi muscle (Fig. 10.16).

The anterior serratus muscle is detached from the tip of the scapula, and its origin is sectioned.

The lateralization of the scapula is useful to identify the plane between the muscle and the bone (Fig. 10.17).

The anterior aspect of the scapula is detached. This step is mandatory to identify and preserve the angular branch (Fig. 10.18).

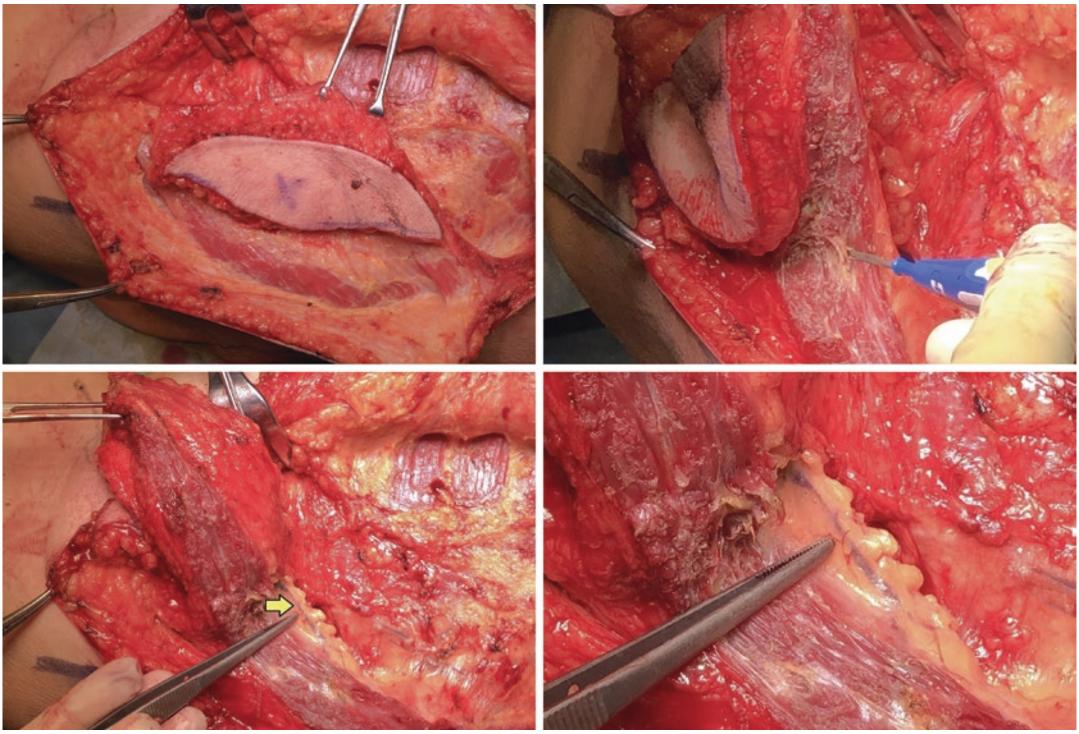

Fig. 10.12 Step 3: posterior skin incision and muscle section. Be careful not to damage the angular branch (yellow arrow)

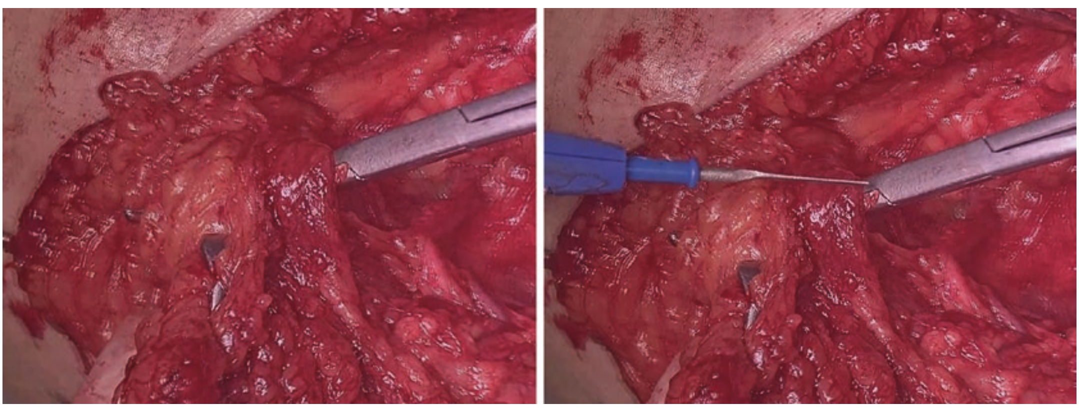

Fig. 10.13 Step 3: section of superior lat dorsi muscle insertion

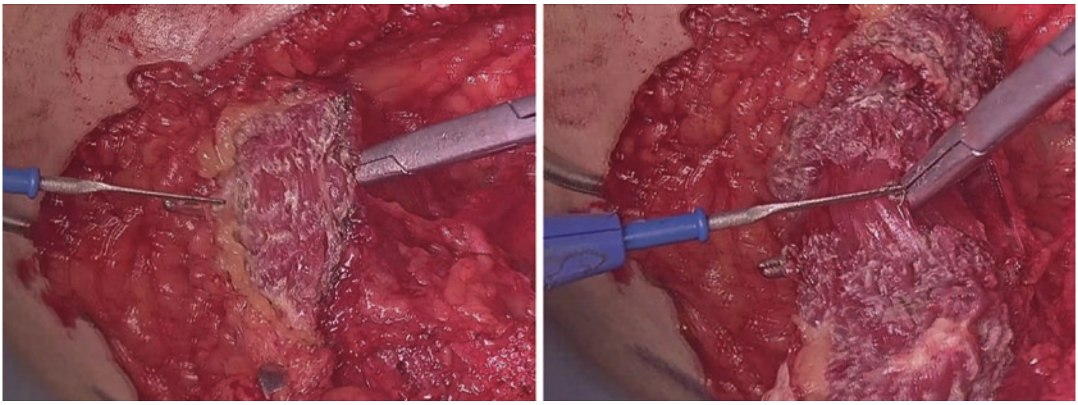

Fig. 10.13 (continued)

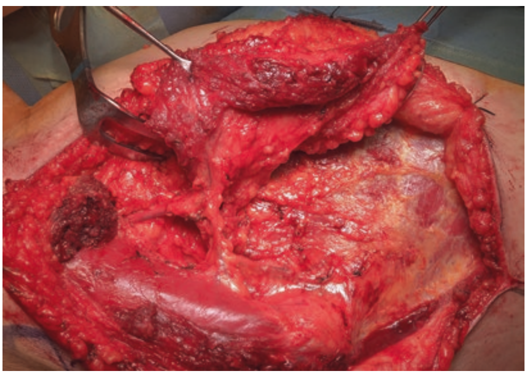

Fig. 10.14 Step 3: lat dorsi flap is displaced anteriorly

The scapula can be harvested as rectilinear bone flap along the lateral edge, or the entire scapula tip can be harvested.

The sections of teres major and minor muscles are required in the point of the osteotomy (Fig. 10.19).

Subsequently, the osteotomy is performed with a reciprocating saw. Piezosurgery can also be used for this step with a long saw tip. It is completed with dissection of the muscles attached anteriorly (Fig. 10.20a, b).

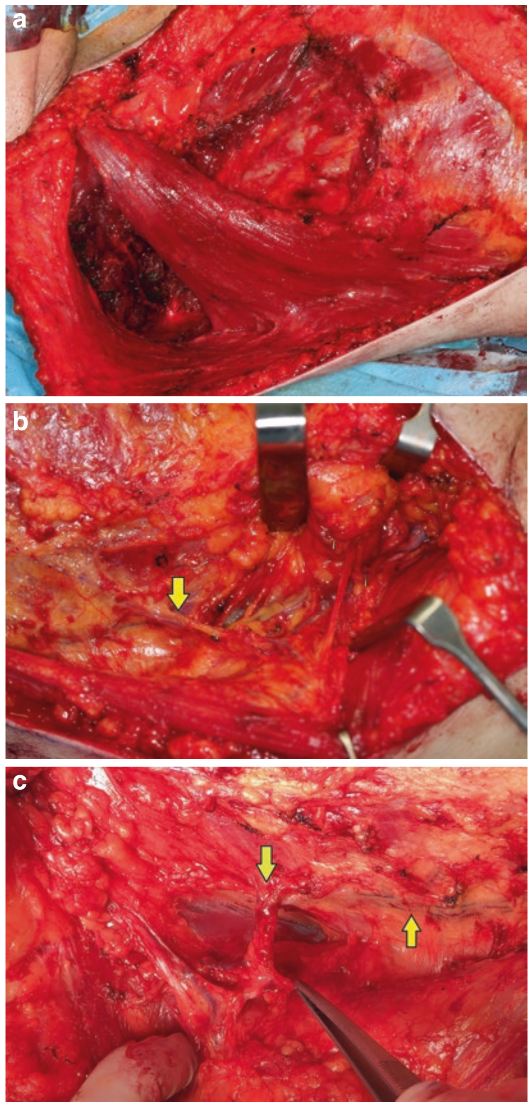

Fig. 10.15 Step 4: anterior serratus muscle can be harvested with its pedicle (yellow arrow)

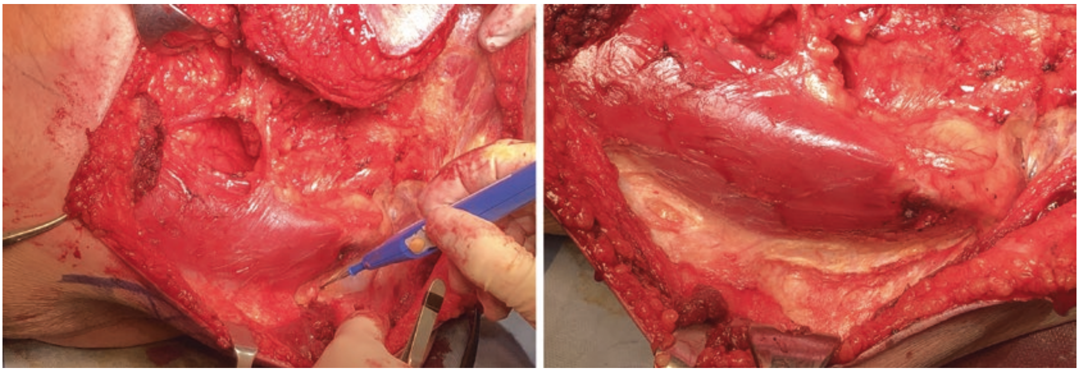

Fig. 10.16 Step 5: posterior scapula dissection

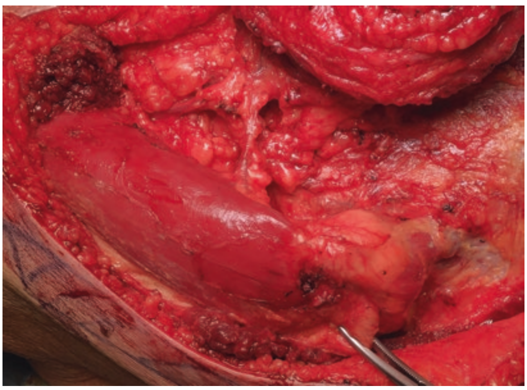

Fig. 10.17 Step 5: lateralization of the scapula tip

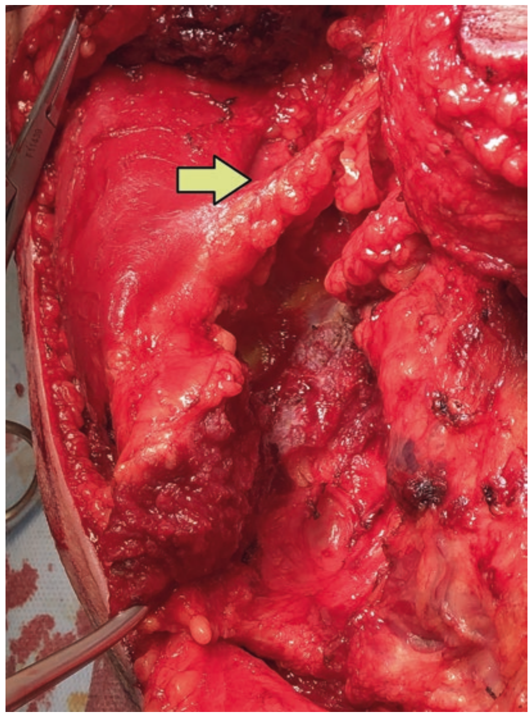

Fig. 10.18 Step 5: anterior aspect of the scapula with angular branch (yellow branch)

10.3.8 Step 6: Complete Dissection of Thoracodorsal Trunk

Branches that are not necessary in the flap are dissected.

Thoracodorsal trunk is followed until it becomes subscapular artery, and all minor collateral arteries are sectioned.

The subscapular artery and vein are followed until their origin from the axillary artery and vein, which must be preserved. At this point, the pedicle is sectioned. When the vascular pedicle is isolated, it will be dissected near its origin (Fig. 10.21).

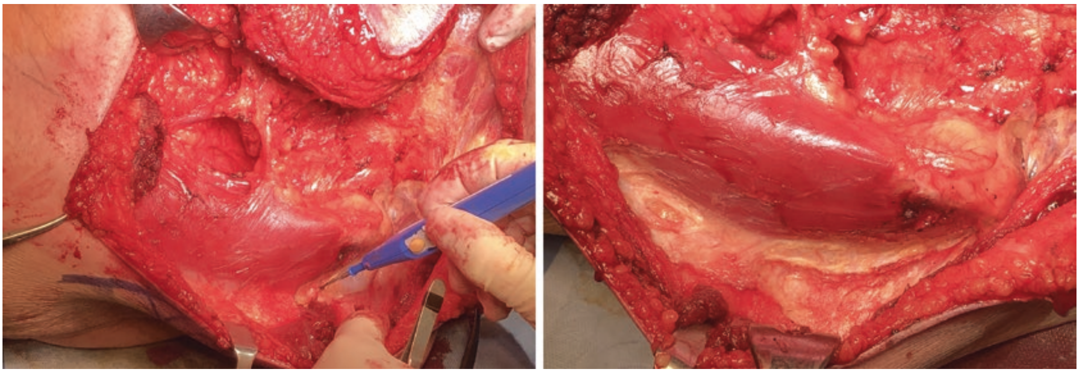

Fig. 10.19 Step 5: scapula is ready for section

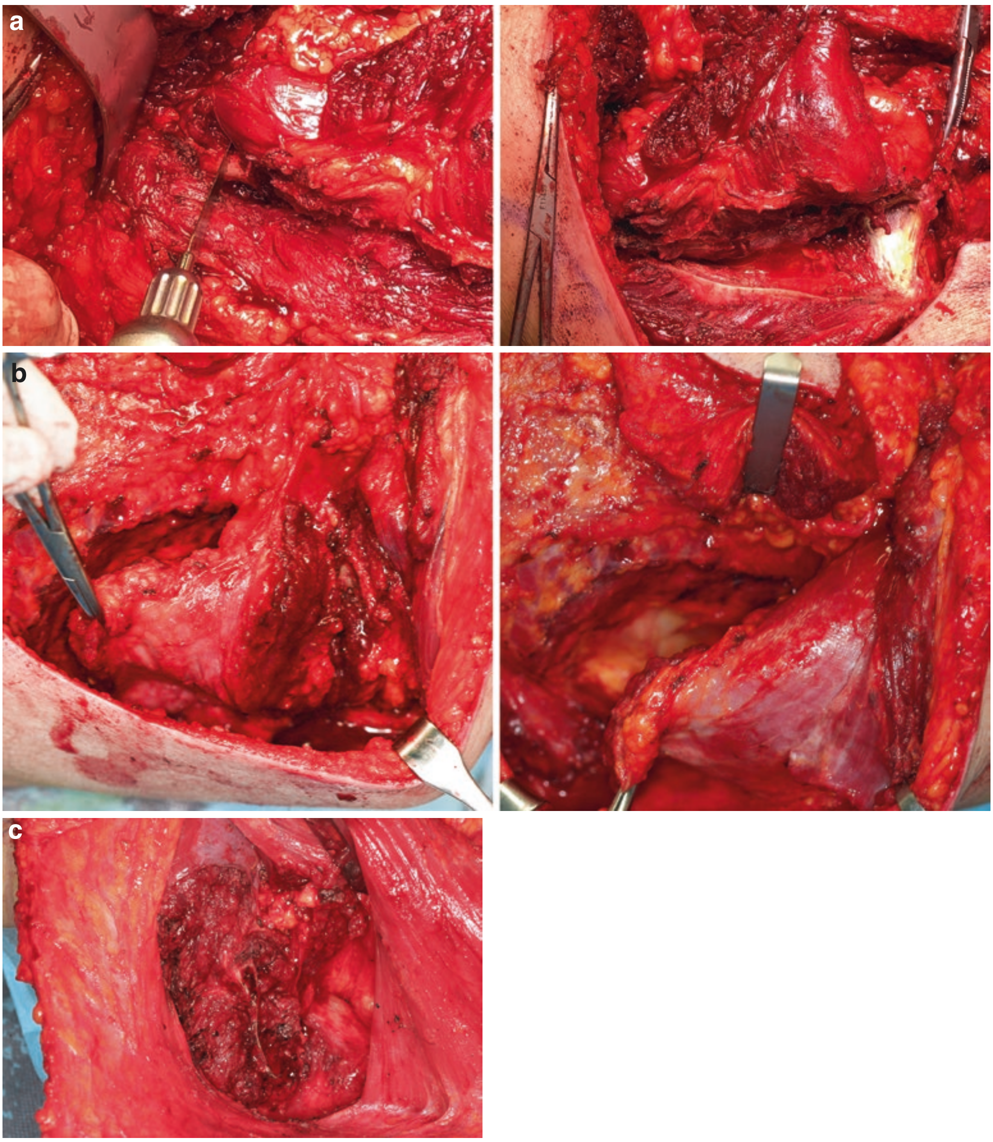

Fig. 10.20 Step 5: osteotomy is performed

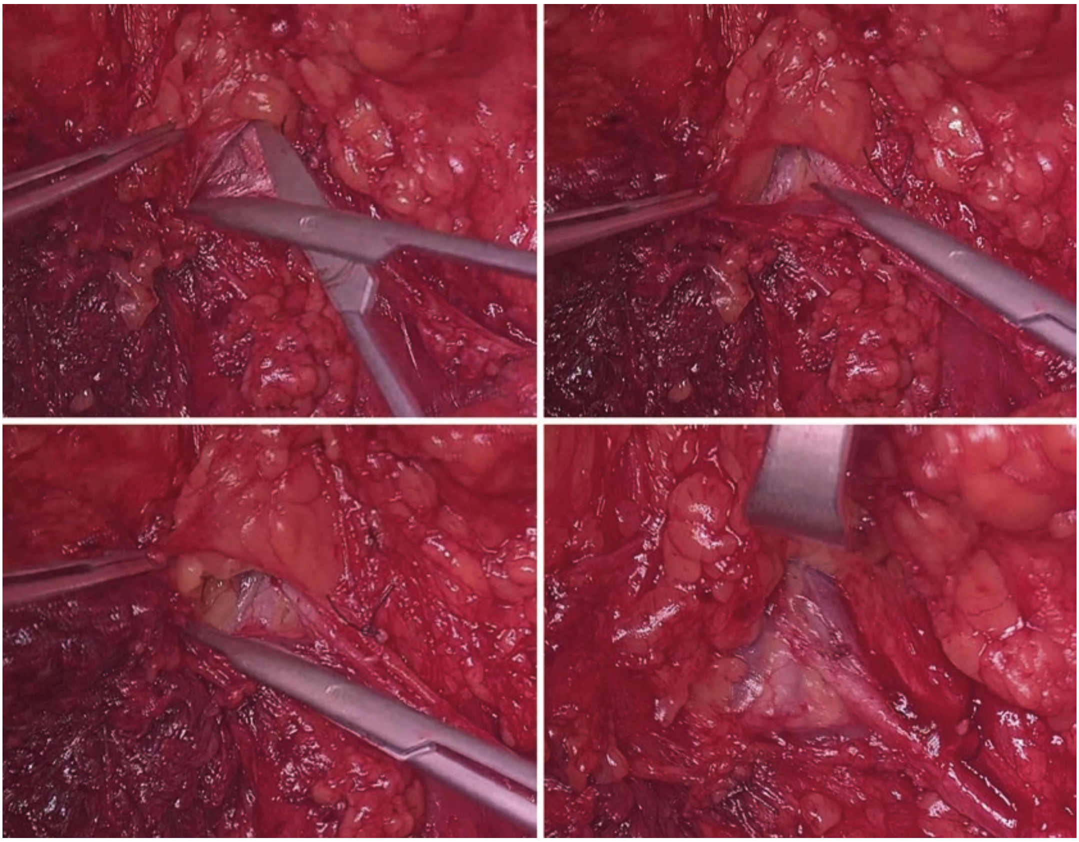

Fig. 10.21 Step 6: thoracodorsal pedicle is dissected until axillary vessels

10.4 Closure of Donor Site

The residual scapula bone is covered by muscular tissue sutured. One or two suction drains are positioned at the caudal portion of the skin incision (Fig. 10.22). Generally, primary closure is achieved (Fig. 10.23). In rare case, a skin graft is needed.

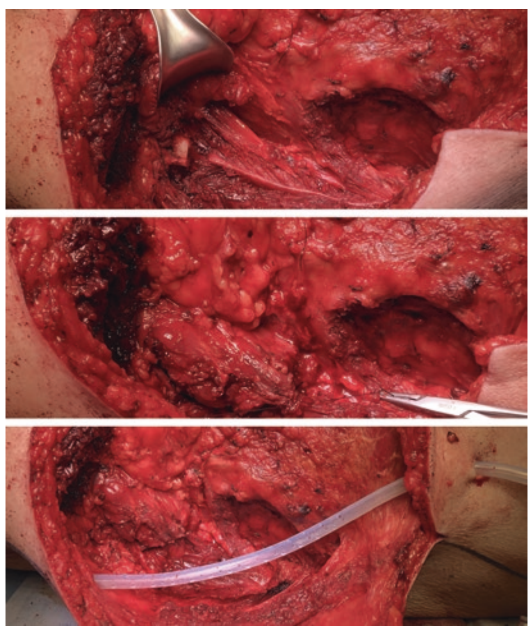

Fig. 10.22 Muscle suture and drain positioning

10.5 Final Appearance of the Chimeric Flaps

- The scapula and the latissimus dorsi flap (Fig. 10.24).
- The tip of the scapula and anterior serratus flap (Fig. 10.25).
- The tip of the scapula plus anterior serratus and latissimus dorsi flap (Fig. 10.26).

Fig. 10.23 Donor site closure

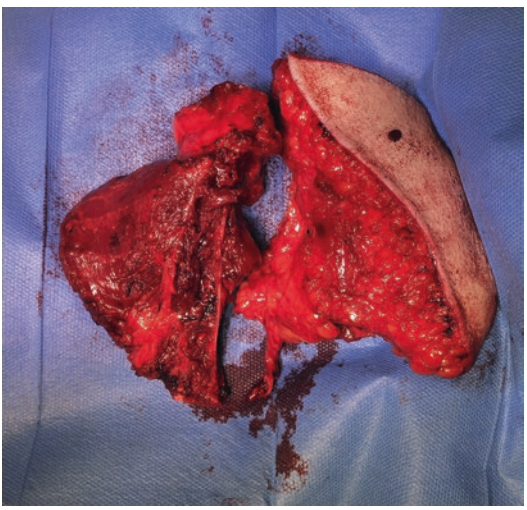

Fig. 10.24 Chimeric flap composed by scapula tip and lat dorsi

Fig. 10.25 Chimeric flap composed by scapula tip and anterior serratus

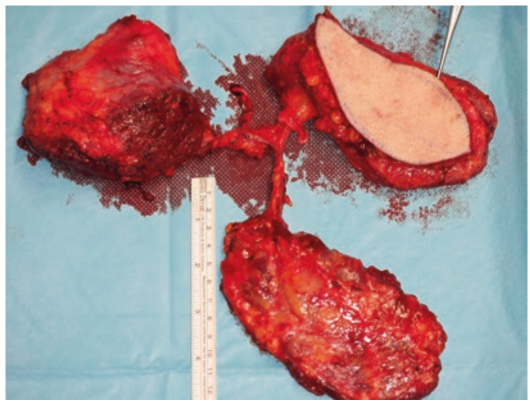

Fig. 10.26 Chimeric flap composed by scapula tip, anterior serratus and lat dorsi

References

1. Gibber MJ, Clain JB, Jacobson AS, Buchbinder D, et al. Subscapular system of flaps: An 8-year experience with 105 patients. Head Neck. 2015;37(8):1200–6.
2. Saijo M. The vascular territories of the dorsal trunk: a reappraisal for potential donor sites. Br J Plast Surg. 1978;31:200.
3. Dos Santos LF. The scapular flap: a new microsurgical free flap. Bol Chir Plast. 1980;70:133.

4. Gilbert A, Teot L. The free scapular flap. Plast Reconstr Surg. 1982;69:601.
5. Nassif TM, Vidal L, Bovet JL, et al. The parascapular flap: a new cutaneous microsurgical free flap. Plast Reconstr Surg. 1982;69:591.
6. Swartz WM, Banis JC, Newton ED, et al. The osteocutaneous scapular flap for mandibular and maxillary reconstruction. Plast Reconstr Surg. 1986;77:530.
7. Deraemaecker R, Thienen C, Lejour M, et al. The serratus anterior—scapular free flap: a new osteomuscular unit for reconstruction after radical head and neck surgery. In: Proceedings of the Second International Conference on Head and Neck Cancer. New York: Springer; 1988. p. 133–7.
8. Rowsell AR, Davis DM, Eisenberg N, et al. The anatomy of the sub-scapular-thoracodorsal arterial system: study of 100 cadaver dissections. Br J Plast Surg. 1984;37:574.
9. O'Connell JE, Bajwa MS, Schache AG, et al. Head and neck reconstruction with free flaps based on the thoracodorsal system. Oral Oncol. 2017;75:46–53.
10. Urken M, Cheney M, Futran N, et al. Atlas of regional and free flaps for head and neck reconstruction: flap harvest and insetting. 2nd ed. Philadelphia: Lippincott Williams & Wilkin; 2012.
11. Jesus RC, Lopes MC, Demarchi GT, et al. The subscapular artery and the thoracodorsal branch: an anatomical study. Folia Morphol (Warsz). 2008;67(1):58–62.
12. Bartlett SP, May JW, Yarernchuk MJ. The latissimus dorsi muscle. A fresh cadaver study of the primary neurovascular pedicle. Plast Reconstr Surg. 1981;67:631.
13. Coleman J, Sultan M. The bipedicled osteocutaneous scapula flap: a new sub- scapular system free flap. Plast Reconstr Surg. 1991;87:682.
14. Seneviratne S, Duong C, Taylor GI. The angular branch of the thoracodorsal artery and its blood supply to the inferior angle of the scapula: an anatomical study. Plast Reconstr Surg. 1999;104:85–8.
15. Seitz A, Papp S, Papp C, Maurer H. The anatomy of the angular branch of the thoracodorsal artery. Cells Tissues Organs. 1999;164(4):227–36.
16. Piazza C, Paderno A, Taglietti V, et al. Evolution of complex palatomaxillary reconstructions: the scapular angle osteomuscular free flap. Curr Opin Otolaryngol Head Neck Surg. 2013;21(2):95–103.
17. Allen RJ, Dupin CL, Dreschnack PA, et al. The latissimus dorsi/scapular bone flap. Plast Reconstr Surg. 1994;94:988.
18. Chepeha DB, Khariwala SS, Chanowski EJP, et al. Thoracodorsal artery scapular tip autogenous transplant. Arch Otolaryngol Head Neck Surg. 2010;136:958–64.
19. Kakibuchi M, Fujikawa M, Hosokawa K, et al. Functional reconstruction of maxilla with free latissimus dorsi-scapular osteomusculocutaneous flap. Plast Reconstr Surg. 2002;109(4):1238–44.
20. Danino AM, Harchaoui A, Malka G. Functional reconstruction of maxilla with free latissimus dorsi-scapular osteomusculocutaneous flap. Plast Reconstr Surg. 2003;112(3):925–6.

11 Iliac Crest Free Flap

S. Ferrari, A. Ferri, B. Bianchi, and E. Sesenna

11.1 Introduction

In 1989, Taylor et al. first described an iliac crest free flap based on the deep circumflex iliac artery (DCIA) and deep circumflex iliac vein (DCIV). Ramasastri et al. showed that the ascending branch of the DCIA provides vascularization to the oblique muscle and skin, thereby creating the composite iliac crest free flap used today. The flap has unique features that have made it a mainstay of treatment, especially in the reconstruction of the head and neck area. The flap is an ideal source of bone when height is needed and, in such cases, is usually preferred to the next most commonly used flap, the fibula free flap. However, some difficulties in harvesting, the short and small-caliber pedicle vessels, and the possibility of donor-site morbidity have reduced flap use to some extent. Today, the flap is often considered to be a "third-level flap," used routinely by only a minority of reconstructive surgeons. However, the flap is excellent when bone stock is required to manage head-and-neck defects, as in mandibular and maxillary reconstruction.

S. Ferrari · A. Ferri (✉) · B. Bianchi · E. Sesenna
Maxillo-Facial Surgery Division, Haed and Neck Department, University Hospital of Parma, Parma, Italy

11.2 Anatomy

The DCIA arises from the external iliac artery about 2 cm proximal to the inguinal ligament. The DCIA then runs together with its vein in the virtual space between the transversus abdominis and iliacus muscles, at a variable distance (from a few millimeters to 3 cm) from the crest of the ilium. The arterial pedicle usually lies 5–8 cm distant from the anterior superior iliac spine (ASIS), whereas the vein is commonly somewhat more remote because it runs in a more medial position before entering the external iliac vein.

During its course, usually proximal to the ASIS and close to the inner surface of the ilium, the DCIA donates an ascending branch to the internal oblique muscle that lies between the external oblique and transversus abdominis muscles; this branch is ideal for head-and-neck soft-tissue reconstruction in almost all cases. The ascending branch is the dominant vascular supply to the internal oblique muscle. The branch also provides some perforators to the bone and should always be preserved when osteomuscular harvesting is planned. The anatomy is constant. For safe pedicle identification, the ascending branch can be easily located in the ventral aspect of the internal oblique muscle and followed to its origin in the DCIA, thereby ensuring safe and easy access to the flap pedicle.

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https://doi.org/10.1007/978-3-030-29582-0_11

11.3 Analytical Factors and Technical Considerations

11.3.1 Mandibular Reconstruction

The flap affords several advantages when used in mandibular reconstruction. The extent of bone in the flap enables precise restoration of mandibular height, especially in dentate patients, and when body and angle defects are approached. The iliac bone is an ideal dental implant, enabling optimal dental rehabilitation. The internal oblique muscle can be used for mucosal reconstruction; the muscle usually exhibits re-epithelization after a few weeks, ensuring ideal restoration of the mucosal lining and improving the quality of peri-implant soft tissues when dental rehabilitation is planned, to a better extent than the skin (which is mobile and thick) provided by other flaps, such as the fibula flap. Furthermore, the pedicle length and small-caliber vessels are usually not problematic during "standard" mandibular reconstruction because of the proximity of the flap to recipient vessels in the neck. However, issues may arise in treated or depleted necks.

The natural shape of the ilium also aids reconstruction; osteotomy is obviously possible but is often unnecessary. For this reason, the choice of donor-site side is important during reconstructive planning; the ipsilateral iliac crest is used when an anterior pedicle exit is preferred and when the upper cortical margin is to be placed in the teeth-bearing area. However, when the inferior (cut) surface of the bone is preferred in the teeth-bearing area, a contralateral flap is used to maintain the anterior pedicle exit. When posterior vessel exit is preferred and the upper border of the ilium is to be employed to reconstruct the mandibular crest, an ipsilateral flap is used; a contralateral flap is chosen when the sectioned border of the ilium is to be employed for this purpose.

A skin paddle can be harvested, but with the exception of composite through-and-through defects and very extensive, three-dimensionally complex oral cavity defects, the internal oblique muscle is usually preferred for soft-tissue reconstruction because of the reliability of the procedure, the large amount of muscle that can be harvested, muscle mobility, and (especially) the already-mentioned capacity for "mucosalization," thereby improving internal lining reconstruction.

11.3.2 Maxillary Reconstruction

The restoration of extended maxillary defects, especially those in the vertical dimension and including the maxillary buttresses, orbital rim, and malar bone, is probably the most satisfying procedure performed by head-and-neck surgeons. The unique bone height of the iliac crest free flap ensures optimal support of the nose and cheek, enabling ideal reconstruction of the orbital rim and providing ideal bone for dental implant placement. In addition, the ability to model the harvested bone with reference to a template of the defects enables precise reconstruction, further improving the esthetic results.

However, the short pedicle is certainly a great disadvantage when maxillary defects are approached; the use of pedicle elongation techniques is often required. In this context, we suggest that a vascular graft should be the last option, given the possibility of microvascular complications. In such cases, an arteriovenous graft (such as an anterolateral thigh free flap pedicle) should be preferred.

We usually manage the short pedicle issue during maxillary reconstruction by first harvesting the flap from a position that is as posterior as possible, to increase vessel length. Furthermore, during neck dissection, preservation of the facial vessels via intraoral anastomosis or isolation of the recipient vessels in the facial flap used to access the tumor (e.g., during the Weber-Ferguson approach) can reduce the distance to be crossed. The use of a preauricular/lifting approach to access facial vessels close to the flap is an option when neck dissection or Weber-Ferguson access is not performed.

Flap orientation is a key consideration. For lower defects (classes 1–2 s of Brown), horizontal flap insets were formerly preferred because they were thought to optimally support the lip and nose and to provide bicortical bone for dental implant placement. Nowadays, the iliac crest is rarely used to repair lower maxillary defects; other flaps, such as scapular tip or fibula flaps, are preferred because of their longer and larger pedicles. However, when an iliac crest flap is selected, a vertical inset is preferred because it facilitates definition of the best shape for reconstruction. Palatal bone reconstruction may not be essential if adequate soft-tissue separation between the oral and nasal cavities is ensured. When higher defects (classes 3–4 s of Brown) are managed, vertical insets restore the maxillary buttresses and malar bone, providing ideal support to the cheek and nose and allowing reconstruction of the orbital rim.

11.4 Flap Harvesting

11.4.1 Patient Positioning and Flap Design (Fig. 11.1)

The patient is placed in the supine position. The area between the inferior costal border and the groin is exposed. Placement of a support below the hip is useful to provide a little extra rotation, increasing visibility during flap dissection. The flap landmarks are the inferior costal border, the inferior border of the scapula, and, especially, the ASIS. The iliac crest is palpated and outlined. An incision line is drawn from the ASIS to the inferior border of the scapula, parallel to the crest but 2 cm medial to it. The costal border is also outlined to define the limit of dissection.

11.4.2 Surgical Steps

11.4.2.1 Step 1

The cutaneous and subcutaneous layers are incised along the designated line using a blade or electric scalpel, for 20 cm, of which 5–7 cm lies caudal to the ASIS. The subcutaneous fat layer thickness depends on patient habitus (Fig. 11.2).

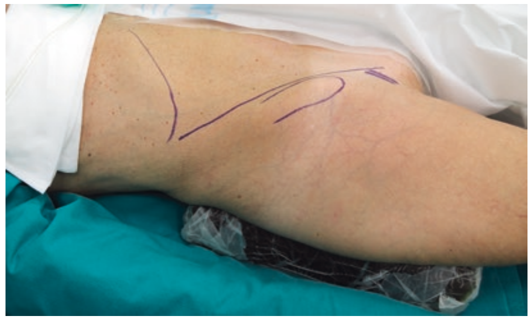

Fig. 11.1 Flap design

Fig. 11.2 Step 1: Cutaneous incision

11.4.2.2 Step 2

The external oblique muscle and its aponeurosis are exposed below the subcutaneous fat tissue, and a cuff featuring about 2 cm of the muscle is formed around the iliac crest for inclusion in the flap (Fig. 11.3).

11.4.2.3 Step 3

The external oblique muscle is incised, preserving the cuff along the crest, and the muscle is then exposed. This elevation plane is quite avascular, and blunt dissection is easy (Fig. 11.4).

Care must be taken when approaching the posterior part of the muscle, where the iliac crest naturally bends medially, to avoid excessive inclusion of the external oblique muscle in the flap. Frequent palpation of the iliac crest bone to ensure correct positioning is useful. The entire oblique internal muscle is exposed, and the amount of cuff needed for reconstruction is outlined (Fig. 11.5).

Fig. 11.3 Step 2: Exposure of external oblique muscle

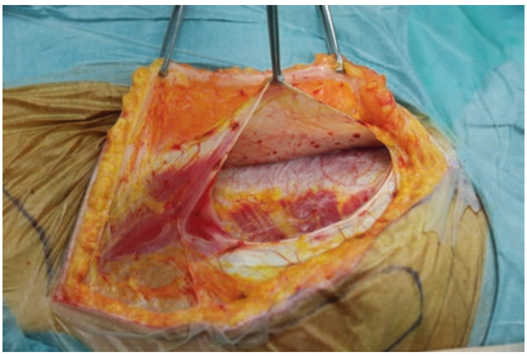

Fig. 11.4 Step 3: Incision and elevation of the external oblique muscle and exposure of the internal oblique muscle

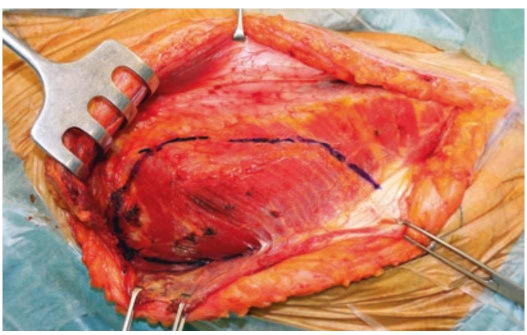

Fig. 11.5 Step 3: Complete exposure of the internal oblique muscle and delimitation of the muscle paddle of the flap

11.4.2.4 Step 4

The muscle is incised up to the transversus abdominis muscle following the designated line, beginning from the medial area (Fig. 11.6). The plane between the two muscles is not always easy to identify; it is usually most obvious near the last rib. The different directions of the muscle fibers are also helpful. Obviously, the attachment of the internal oblique muscle to the crest must not be interrupted.

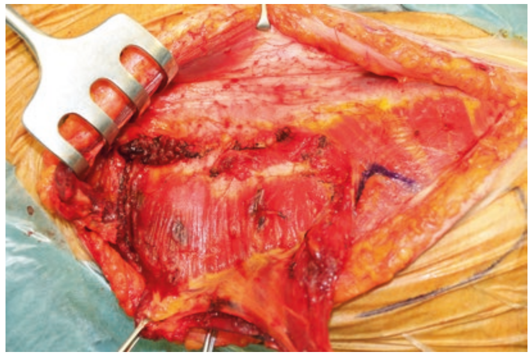

Fig. 11.6 Step 4: Incision and elevation of the internal oblique muscle paddle

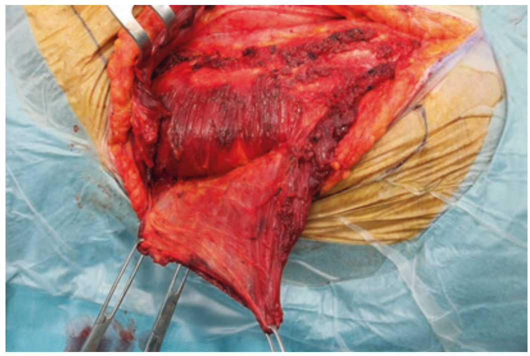

Fig. 11.7 Step 5: Complete elevation of the internal oblique muscle and exposure of the transversus muscle

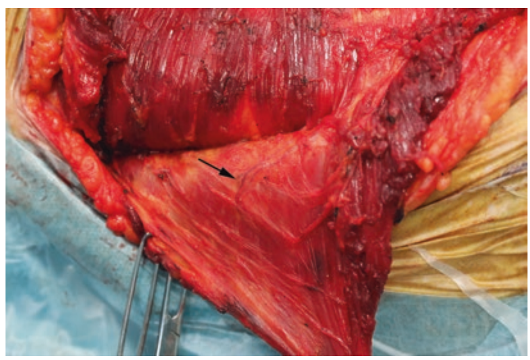

Fig. 11.8 Step 5: Identification of the ascending branch of the DCIA

11.4.2.5 Step 5

The muscle is then elevated (in a medial-to-distal sequence) from the transversus, with careful cauterization of all intramuscular vessels (Fig. 11.7).

During this maneuver, the ascending branch of the DCIA that supplies the muscle is identified in the ventral surface of the muscle (Fig. 11.8, arrow).

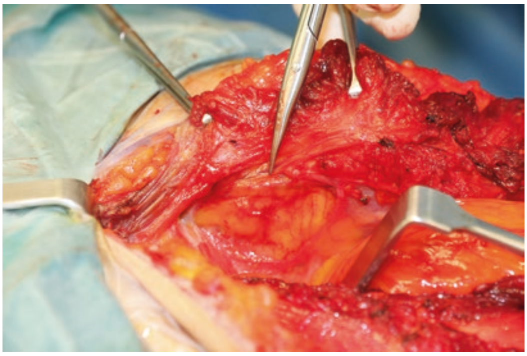

Fig. 11.9 Step 6: Identification of the flap pedicle

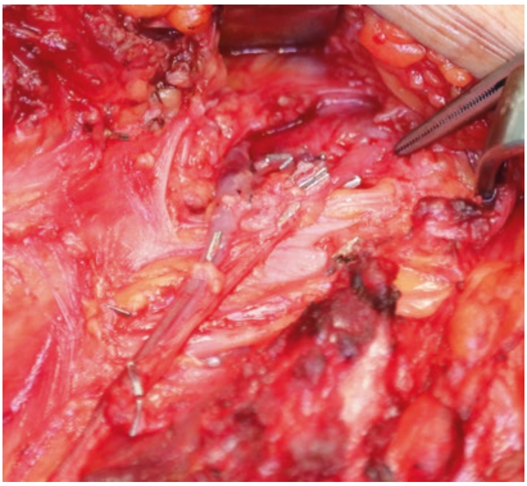

Fig. 11.10 Step 6: Dissection of the vascular pedicle

11.4.2.6 Step 6

The ascending branch is followed distally during dissection until it enters the DCIA, enabling safe and reliable identification of the vascular pedicle of the flap (Fig. 11.9).

Once identified, the DCIA and DCIV are dissected from the surrounding tissue up to their junctions with the external iliac artery and vein, with care taken to ligate or coagulate vascular branches that are not to be included in the flap (Fig. 11.10).

11.4.2.7 Step 7

The transversus abdominis muscle is incised about 2 cm distal to the iliac crest (Fig. 11.11) to create a muscle cuff protecting the vascular pedicle (which should not be proximally exposed to the ASIS).

After incision of the transversus, the preperitoneal fat must be retracted to expose the iliacus muscle over the inner surface of the iliac bone (Fig. 11.12).

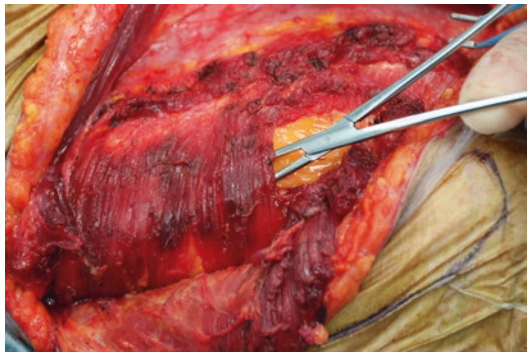

Fig. 11.11 Step 7: Incision of the transversus muscle

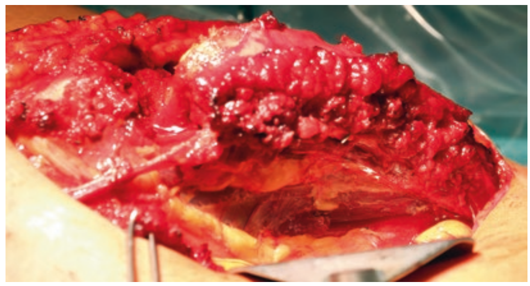

Fig. 11.12 Step 7: Exposure of the iliacus muscle

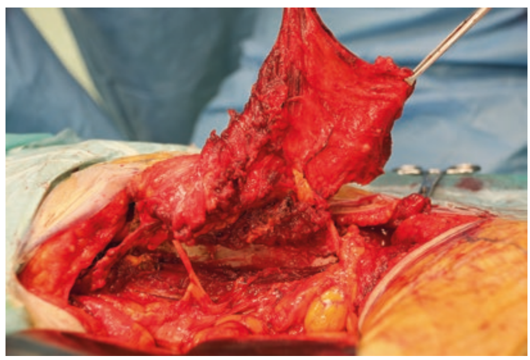

Fig. 11.13 Step 8: Exposure of the inner table of the iliac bone

Once exposed, that muscle is sectioned, preserving about 2 cm to protect the vascular pedicle that at this point runs between the iliacus and transversus muscles, where its pulsation can be palpated.

11.4.2.8 Step 8

The inner surface of the bone is thus exposed (Fig. 11.13).

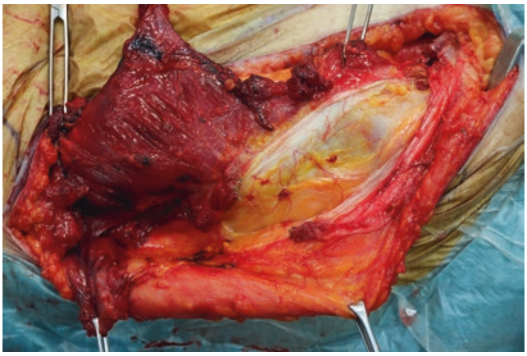

Fig. 11.14 Step 9: Dissection of the external surface of the crest

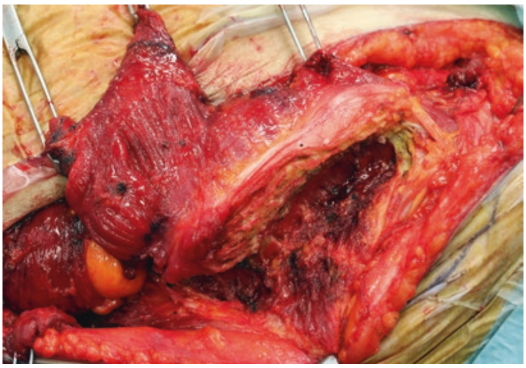

Fig. 11.15 Step 9: Exposure of the external surface of the iliac bone

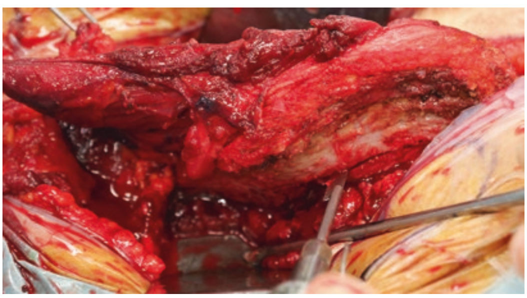

Fig. 11.16 Step 10: Bone section

11.4.2.9 Step 9

When skin harvesting is not planned (as is usually the case), dissection continues on the external surface of the crest (Fig. 11.14), where the insertions of the gluteus, sartorius, and tensor fasciae latae are sectioned to skeletonize the outer side of the iliac bone prior to bone harvesting (Fig. 11.15).

The posterior insertions of the oblique and transversus muscles are then sectioned, taking care to coagulate the posterior portion of the vascular pedicle (or to ligate it if it is identified), which is usually small in this area.

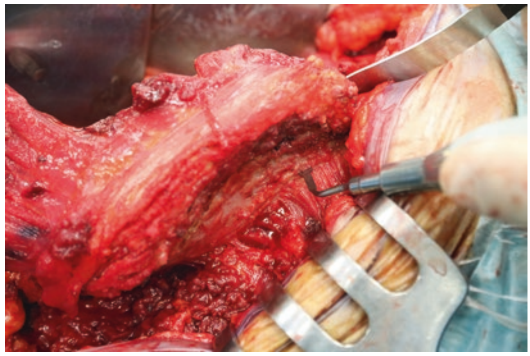

Fig. 11.17 Step 10: Bone section with piezosurgery

11.4.2.10 Step 10

Next, a protector is placed on the inner surface of the flap to protect the pedicle from the cutting instruments, and osteotomy of the iliac crest is performed from the external side of the ilium basing on the size and shape of the defect to be reconstructed (Fig. 11.16).

Use of a piezoelectric scalpel is very useful at this stage, as it enhances safety and precision (Fig. 11.17).

11.4.2.11 Step 11

Once the flap is mobilized, muscles anterior to the ASIS, including the iliopsoas and sartorius, are sectioned, with care always taken to protect the vascular pedicle from accidental injury. At this time, the lateral femoral cutaneous nerve must be identified and preserved [Fig. 11.18**a**, external view of the nerve; b, internal view of the nerve (arrow)].

11.4.2.12 Step 12

After complete flap mobilization (Fig. 11.19) and preparation of the recipient vessels, the DCIA and DCIV are ligated at their junctions with the external iliac vessels, and the flap is ready for transplantation (Fig. 11.20).

11.5 Donor-Site Closure

One of the main concerns with the use of iliac crest free flaps is the possibility of severe donor-site complications. Violation of the abdominal

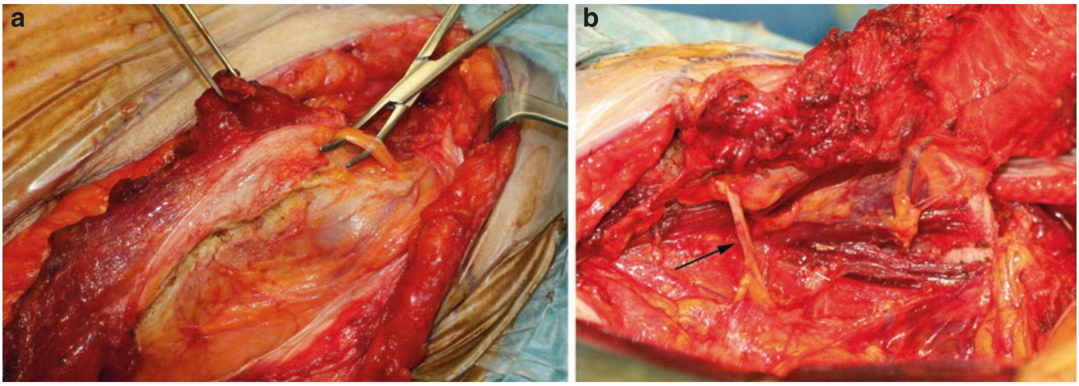

Fig. 11.18 Step 11: (**a**) External view of the nerve; (**b**) internal view of the nerve (arrow)

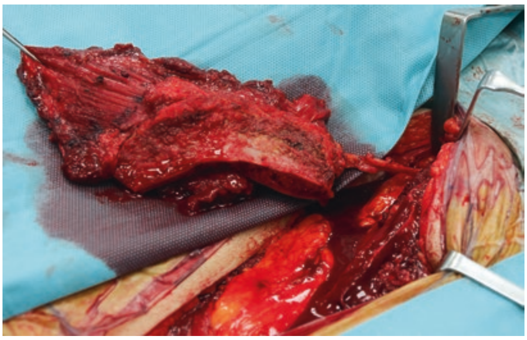

Fig. 11.19 Step 12: Flap elevation

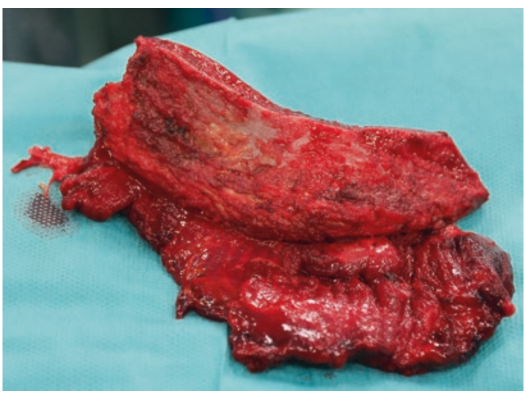

Fig. 11.20 Step 12: Iliac crest osteomuscular flap harvested

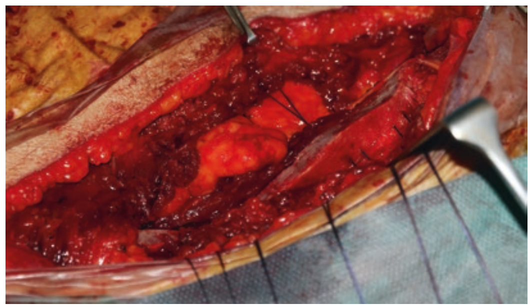

Fig. 11.21 Drilling of the iliac bone and placement of sutures

wall and disruption of the abdominal muscle insertions on the ilium may trigger an abdominal hernia requiring further surgery, particularly in obese patients. Indeed, sometimes, obesity is a contraindication to flap harvesting. Furthermore, massive donor-site dissection may trigger hematoma formation that can be further complicated by superinfection requiring long-term hospital care and creating patient discomfort. To prevent such complications, extremely careful donor-site closure, if possible by an experienced surgeon, is essential. During wound closure, care must be taken to insert muscle remnants into holes drilled in the residual iliac bone (Fig. 11.21); sutures that include the remnants of the iliacus and transversus should be fixed to these holes to restore abdominal wall competence (Fig. 11.22).

The second layer should approximate the internal oblique muscle and the gluteus, sartorius, and tensor fasciae latae. Placement of a mesh is mandatory after harvesting of the large oblique muscle (Fig. 11.23).

The remnants of the external oblique aponeurosis are then sutured to finalize deep closure of the donor site, and two suction drainages are placed, one deep and one superficial to the external aponeurosis (Fig. 11.24).

Postoperative donor-site care is important; the patient should stay in bed for at least 3 days

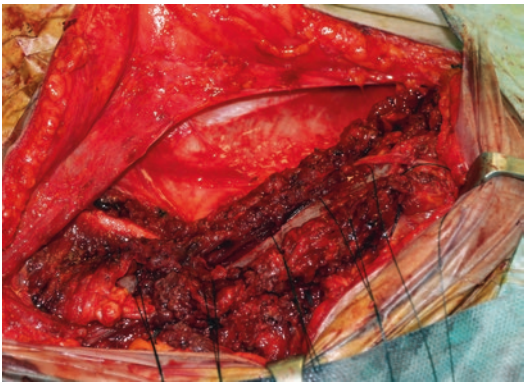

Fig. 11.22 Closure of the deep muscle layer

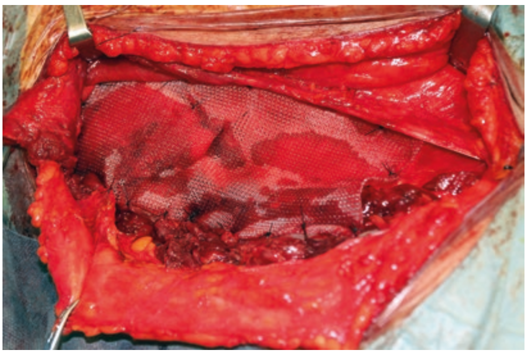

Fig. 11.23 A mesh can be used to reinforce the closure

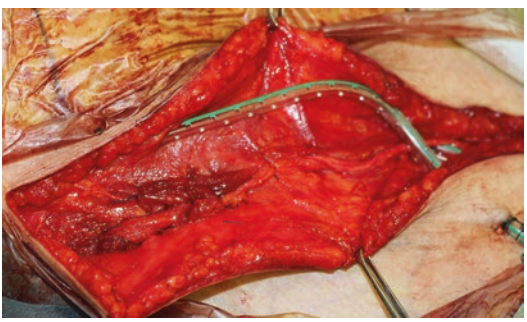

Fig. 11.24 Closure of the external oblique muscle and its aponeurosis

and should be mobilized only with a compression dressing to prevent herniation of abdominal contents. Careful daily checks for possible complications should be scheduled, and ultrasonography or computed tomography should be performed in suspect cases. Ambulation should be restored only after evaluation by a rehabilitative specialist, and crutches should be used for the first month. Postoperative rehabilitation should also be performed with the goal of improving functional outcomes.

Further Reading

Bianchi B, Copelli C, Ferrari S, Ferri A, Sesenna E. Anterolateral thigh flap pedicle for interposition artery and vein grafts in head and neck reconstruction: A case report. Microsurgery. 2009;29(2):136–7.

Bianchi B, Ferri A, Ferrari S, Copelli C, Boni P, Sesenna E. Iliac crest free flap for maxillary reconstruction. J Oral Maxillofac Surg. 2010;68:2706–13.

Bianchi B, Ferri A, Ferrari S, Copelli C, Sesenna E. Facelift approach for mandibular resection and reconstruction. Head Neck. 2014;36(10):1497–502.

Bianchi B, Ferri A, Ferrari S, Copelli C, Sesenna E. Iliac crest free flap and submental island flap association for maxillary reconstruction: report of a case. Scand J Plast Reconstr Surg. 2013;47:538–42.

Brown JS, Rogers SN, McNally DN, Boyle M. A modified classification for the maxillectomy defect. Head Neck. 2000;22:17–26.

Brown JS. Deep circumflex iliac artery free flap with internal oblique muscle as a new method of immediate reconstruction of maxillectomy defect. Head Neck. 1996;18:412–21.

Clark JR, Vesely M, Gilbert RW. Scapular angle osteomyocutaneous flap in postmaxillectomy reconstruction: defect, reconstruction, shoulder function, and harvest technique. Head Neck. 2008;30:10–20.

Cordeiro PG, Santamaria E, Kraus DH, Strong EW, Shah JP. Reconstruction of total maxillectomy defects with preservation of the orbital contents. Plast Reconstr Surg. 1998;102:1874.

Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. Plast Reconstr Surg. 2000a;105:2331–46.

Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. Plast Reconstr Surg. 2000b;105:2331–46.

Genden EM, Wallace D, Buchbinder D, Okay D, Urken ML. Iliac crest internal oblique osteomusculocutaneous free flap reconstruction of the postablative palatomaxillary defect. Arch Otolaryngol Head Neck Surg. 2001;127:854–61.

Lonie S, Herle P, Paddle A, Pradhan N, Birch T, Shayan R. Mandibular reconstruction: meta-analysis of iliac- versus fibula-free flaps. ANZ J Surg. 2016;86(5):337–42.

Santamaria E, Cordeiro PG. Reconstruction of maxillectomy and midfacial defects with free tissue transfer. J Surg Oncol. 2006;94:522–31.

Shrime MG, Gilbert RW. Reconstruction of the midface and maxilla. Facial Plast Surg Clin N Am. 2009;17:211–23.

Spiro RH, Strong EW, Shah JP. Maxillectomy and its classification. Head Neck. 1997;19:309–16.

Urken ML, Cheney ML, Sullivan MJ, Biller HF. Atlas of regional and free flaps for head and neck reconstruction. New York: Raven press; 1994.

Urken ML, Vickery C, Weinberg H, Buchbinder D, Lawson W, Biller HF. The internal oblique-iliac crest osseomyocutaneous free flap in oromandibular reconstruction. Report of 20 cases. Arch Otolaryngol Head Neck Surg. 1989;115:339–49.

The Medial Femoral Condyle Flap

12

M. Cherubino, D. Sallam, and P. L. Tos

12.1 Introduction

The medial femoral condyle (MFC) flap represents a valid source of thin and pliable sheet of corticoperiosteal tissue with or without cancellous bone [1, 2]. The highly osteogenic nature of the periosteum combined with its excellent vascularity after microvascular transfer achieves a high success rate in many scenarios. Most common indications for the MFC flap include bone nonunions [3–5] with or without segmental bone loss and total bone and cartilage reconstruction [6, 7]. Flap variations can incorporate also cancellous bone, muscle, tendon, cartilage, and/or skin. The flap has been used for several distrect as nasal reconstrction [8] or thumb [9].

12.2 Anatomy

The medial femoral condyle flap is supplied by the descending genicular artery (DGA), a branch of the superficial femoral artery. The superficial femoral system passes through the hiatus in the *adductor magnus* to enter the popliteal space and becomes the popliteal artery and vein. The descending genicular artery (DGA) origins from the femoral system above the hiatus. This branch runs deep or lateral to the adductor magnus tendon along the posterior aspect of the medial intermuscular septum and coalesces with the superomedial genicular artery (SGA).

The DGA typically has three branches including an articular branch, a muscular branch, and a saphenous branch. The articular branch feeds the periosteum and the articular cartilage on the superior femoral condyle. This branch is the main pedicle for the medial femoral condyle flap. The muscular branch supplies the *vastus medialis* muscle, and the *saphenous* branch supplies the subcutaneous tissue and overlying skin [4].

The SGA originates from the proximal portion of the popliteal artery. The vessel crosses from behind the *adductor magnus* tendon to anastomose with the osteoarticular branch of the DGA contributing to the perforating vessels over the condyle. This artery represents the secondary pedicle of the flap and arises near the level of the muscle hiatus. These two arteries create a vascular periosteal plexus just above the medial collateral ligament and the joint capsule of the knee that supplies the medial femoral condyle flap. The medial superior genicular is a shorter branch, and although the flap could be taken on this branch, it is preferably taken on the descending

M. Cherubino (✉) · D. Sallam
Plastic Surgery Department, University of Insubria, Varese, Italy

P. L. Tos
Department of Orthopaedics and Traumatology for Hand, ASST Gaetano Pini, Milan, Italy

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genicular to supply a longer vascular leash. Nevertheless, in 10–15% of patients, the SGA is the main pedicle because the descending genicu-late artery is absent or diminutive.

12.3 Analytical Factors and Technical Considerations

Anatomic variation exists within the arterial ped-icle, and the DGA may be absent in up to 10% of patients. If the DGA is absent, one can still ele-vate the flap on the SGA, though its pedicle will be shorter.

12.4 Flap Harvesting

12.4.1 Preoperative Management

12.4.2 Patient Positioning

The patient is placed supine with the leg abducted and flexed in a frog-like position to expose the medial surface of the knee. A tourniquet is optional but helpful.

12.4.2.1 Flap Design

A point between the medial aspect of the patella and the prominence of the medial femoral con-dyle marks the distal aspect of the incision. The incision can prolugate if necessary during the harvest. A longitudinal line is marked proximally and over the adductor hiatus. The skin incision of about 12–16 cm length (Fig. 12.1).

12.4.2.2 Step 1

Incision is performed and must include the der-mis and underlying adipose tissue until it reaches the fascial layer that is also delicately incised. During subcutaneous dissection, care is made to identify perforator to the skin, from the saphe-nous branch, that could include a small skin island if a chimeric flap is planned. The muscular fascia is incised, and the *vastus medialis* muscle is dissected from its septal fascial attachments and retracted anteriorly (Fig. 12.2).

Fig. 12.1 A point between the medial aspect of the patella and the prominence of the medial femoral condyle marks the distal aspect of the incision

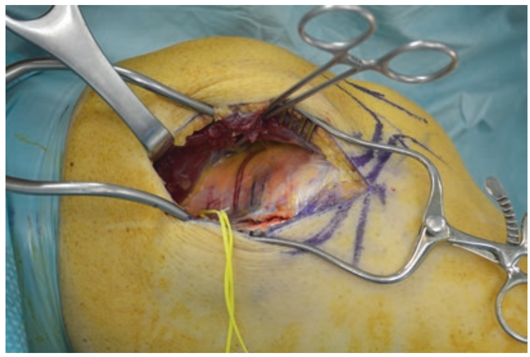


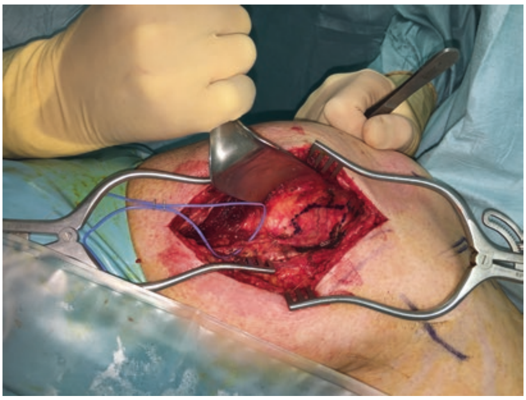
Fig. 12.2 Osteoarticular perforators vessels on the con-dyle are identified, and retrograde dissection is performed to reach the DGA

12.4.2.3 Step 2

The main pedicle, the DGA, is identified with the osteoarticular perforators. It's better to Start the dis-section distaly, on the medial condyle. There is a layer of connective tissue on top of the vessels on the medial femoral condyle that must be remove to iden-tificate the osteoarticular perforators. The proximal descending genicular artery, with its comitant veins, lies deep to the roof of the adductor canal and pro-ceeds distally dividing into three branches: the mus-cular branches, the osteoarticular branch, and the saphenous branch. The branches of the artery are identified and isolated as they enter the periosteum of the femur. Retrograde dissection then begins over the DGA back to its origin at the adductor canal. The tendon of *adductor magnus* lies on the floor of the dissection. The osteoarticular branch is identified and traced distally along its course adjacent to the *adductor magnus* tendon, while all collateral vessels are ligated or cauterized (Fig. 12.3).

12.4.2.4 Step 3

At the level of the medial condyle, the osteoarticular vessel divides in several branches that disperse over the corticoperiosteal surface of the medial supracondylar femur. Here, the area of the flap is measured and marked: a rectangle of adequate dimension corresponding the defect is elevated. If the osteocartilaginous flap is not necessary, the knee joint should be spared. Care is taken to protect the articular surface and the medial collateral ligament during harvest of the vascularized bone flap.



12.4.2.5 Step 4

The periosteum is cut with cautery, and the cortex is elevated with a chisel or electric saw. Osteotomes are used to elevate the bone flap from the entire perimeter of the corticotomy. Using a curved osteotome, the flap is removed with some cancellous bone, with a thickness of

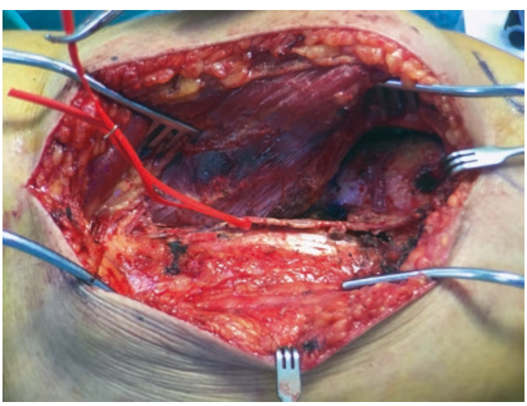


Fig. 12.3 The main pedicle, the DGA after retrograde dissection

about 0.5 cm or less. The distal edge of the flap has to be harvested with particular attention. Only a thin portion of the medulla component should be harvested (Fig. 12.4).

12.4.2.6 Step 5

The entire flap is then isolated on the pedicle, which can be eventually traced back to the point where it pierces the roof of the adductor canal to yield a longer length. Final length of the pedicle is in average 10–12 cm. The donor area is packed with bone wax, and the flap is ligated and divided when the recipient area is ready. The wound is closed in layers over a suction drain, and a compressive dressing is applied. A post-op X-rays must be taken before the end of surgery to secure that no bone fractures occurred.

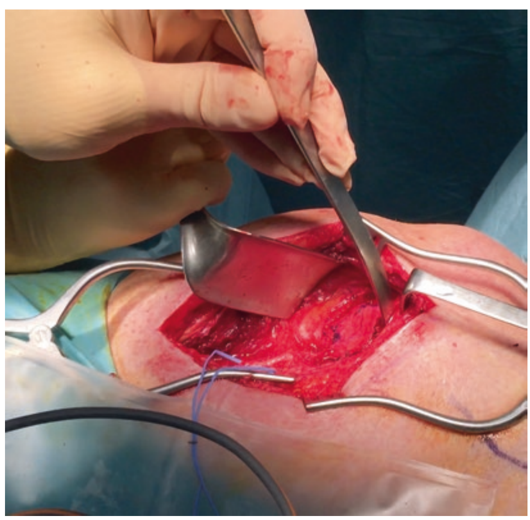


Fig. 12.4 Using a curved osteotome, the flap is removed with some cancellous bone, with a thickness of about 0.5 cm

References

1. Doi K, Hattori Y. Vascularized bone graft from the supracondylar region of the femur. Microsurgery. 2009;29(5):379–84.
2. Bürger H, Windhofer C, Gaggl A, Higgins J. Vascularized medial femoral trochlea osteocartilaginous flap reconstruction of proximal pole scaphoid nonunions. J Hand Surg Am. 2013;38(4):690–700.
3. Del Piñal F, García-Bernal F, Regalado J, Ayala H, Cagigal L, Studer A. Vascularised corticoperiosteal grafts from the medial femoral condyle for difficult non-unions of the upper limb. J Hand Surg Eur Vol. 2007;32(2):135–42.
4. Iorio ML, Masden DL, Higgins JP. Cutaneous angiosome territory of the medial femoral condyle osteocutaneous flap. J Hand Surg Am. 2012;37(5):1033–41.
5. Yamamoto H, Jones D, Moran SL, et al. The arterial anatomy of the medial femoral condyle and its clinical implications. J Hand Surg Eur Vol. 2010;35:569–74.
6. Hugon S, Koninckx A, Barbier O. Vascularized osteochondral graft from the medial femoral trochlea: anatomical study and clinical perspectives. Surg Radiol Anat. 2010;32(9):817–25. https://doi.org/10.1007/s00276-010-0629-1. Epub 2010 Feb 12
7. Fuchs B, Steinmann S, Bishop A. Free vascularized corticoperiosteal bone graft for the treatment of persistent nonunion of the clavicle. J Shoulder Elb Surg. 2005;14(3):264–8.
8. Cherubino M, et al. Medial femoral condyle free flap for nasal reconstruction: new technique for full-thickness nasal defects. Plast Reconstr Surg Glob Open. 2016;4(9):e855.
9. Ruston JC, Amin K, Darhouse N, Sivakumar B, Floyd D. The vascularized medial femoral corticoperiosteal flap for thumb reconstruction. Plast Reconstr Surg Glob Open. 2015;3(8):e492.

Fibula Free Flap

13

G. Molteni, M. Ghirelli, P. Procacci, A. Fior,
R. Nocini, and R. Pellini

13.1 Anatomy (Scheme 13.1)

13.1.1 Compartments of Low Leg

The fibula is a bone located in the lateral portion of the leg measuring approximately 40 cm. It is articulated superiorly with the lateral tibial condyle and inferiorly with the lateral malleolus. The fibula and the tibia are connected to each other through the interosseous membrane.

The lower leg is divided into four compartments: anterior, lateral, posterior, and deep.

The anterior compartment is bounded by interosseous membrane posteriorly, anterior intermuscular septum laterally, and tibia medially. It contains three muscles that, from the medial to the lateral ones, are anterior tibialis, long extensor of the fingers, and extensor along the big toe. In the depth of this compartment, between the first two muscles, we find the anterior tibial peduncle, composed of artery, vein, and nerve.

The Lateral compartment is bounded by an anterior intermuscular septum and posterior intermuscular septum both connected with the fibula. Inside the compartment, there are the muscles peroneus brevis and longus, the most superficial.

The deep posterior compartment contains three muscles bounded by interosseous membrane anteriorly, the transverse intermuscular septum posteriorly and tibia and fibula laterally. From anterior to posterior, the muscles are the tibialis posterior, flexor digitorum longus medially, and flexor hallucis laterally. Furthermore, this compartment contains posterior tibial pedicle composed by artery, vein and the tibial nerve. Peroneal vessels lie between posterior tibial muscle and flexor hallucis.

The posterior compartment includes the soleus, gastrocnemius and plantaris muscles.

13.1.2 Artery and Venous System

The vascular system of the lower extremity begins when popliteal artery gives three main branches: anterior and posterior tibialis arteries and peroneal artery.

G. Molteni (✉) · R. Nocini
Department of Otorhinolaryngology-Head and Neck Surgery, University Hospital of Verona Borgo Trento, Verona, Italy

Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

M. Ghirelli
Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital of Modena, Modena, Italy

P. Procacci · A. Fior
Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy

Maxillofacial Surgery and Dentistry, University Hospital of Verona Borgo Roma, Verona, Italy

R. Pellini
Department of Otolaryngology-Head and Neck Surgery, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

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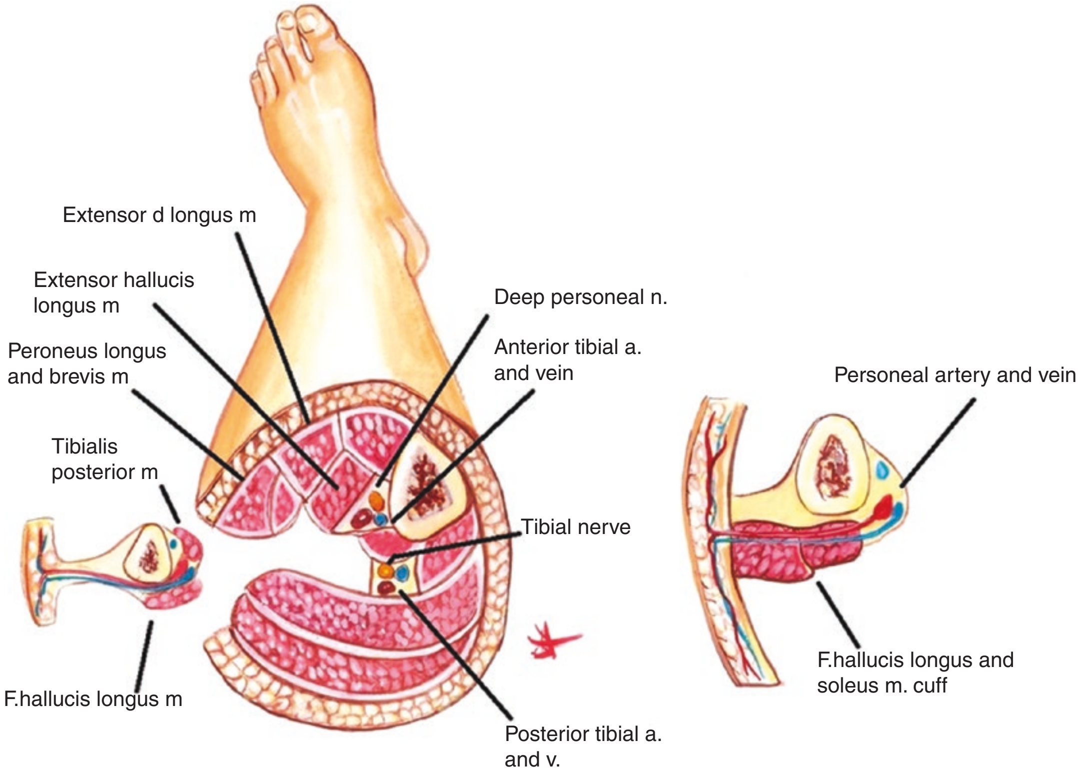


Scheme 13.1 Anatomy of the flap and leg compartments

The most common branching pattern is with tibialis anterior artery arising first followed by the tibial-peroneal trunk, which then gives rise to the posterior tibial artery and peroneal artery. The peroneal artery origins, normally, 2.5 cm under the inferior margin of popliteal muscle and lies into fibrous canal between posterior tibial muscle and flexor hallucis muscle or, less commonly, inside this muscle. In the distal tract near the tibiofibular junction, the artery gives the terminal malleolar and calcanear branches. The mean arterial caliber ranges from 1.5 to 2.5 mm, while the venous caliber from 2 to 3 mm.

The length of the pedicle is approximately 6 cm but can be increased significantly according to the flap design.

13.1.3 Nerves

The motor innervation derives from common peroneal nerve that surrounds the back and outer side of the neck of the fibula between the two heads of the peroneus longus muscle as well as 4–8 cm below the head of the fibula. It divides into the superficial and deep peroneal nerves. The superficial peroneal nerve descends between the extensor digitorum longus and peroneal muscles and supplies the peroneus longus and peroneus brevis muscles.

The deep peroneal nerve passes obliquely forward and downward around the fibular neck between the peroneus longus and the extensor digitorum longus muscles to the front of the interosseous membrane. It descends lateral to the tibialis anterior muscle and is a medial relation first to the extensor digitorum longus muscle and then to the extensor hallucis longus muscle, the tendon of which crosses the nerve obliquely above the ankle. In its downward course, the nerve first lies lateral to the anterior tibial vessels, then anterior to them, and finally lateral to them again in front of the lower end of the tibia and ankle. This nerve supplies the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius muscles. Injury to the common peroneal nerve leaves the patient with an equinovarus deformity and anesthesia along the anterior and lateral sides of the leg and dorsum of the foot. The sensory innervation is supplied by the lateral branch of the sural cutaneous nerve that can be harvested to provide a sensate skin paddle.

13.2 Analytical Factors and Technical Considerations

13.2.1 Vascular Anomalies

Variations in popliteal branching pattern were seen in about 15% of the cases and are classified in three categories from Kim et al. (Fig. 13.1) [1].

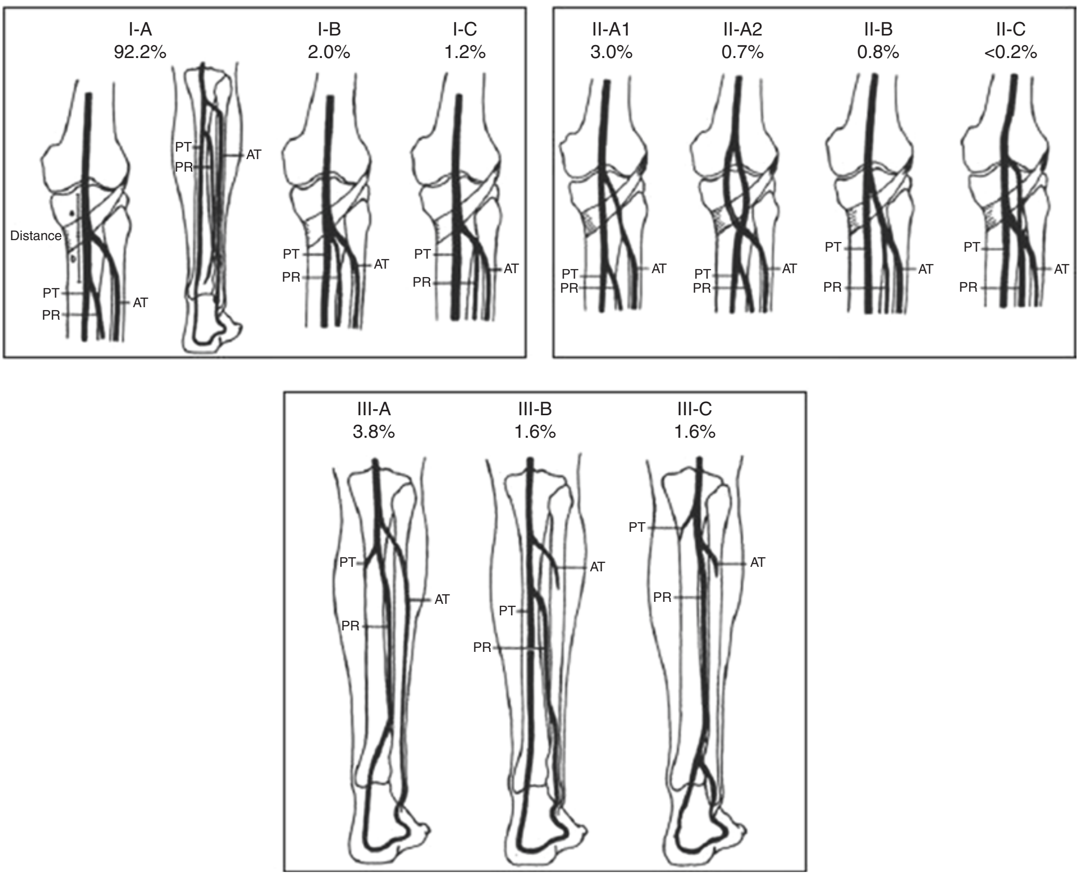


Fig. 13.1 The possible variations of the vascular supply

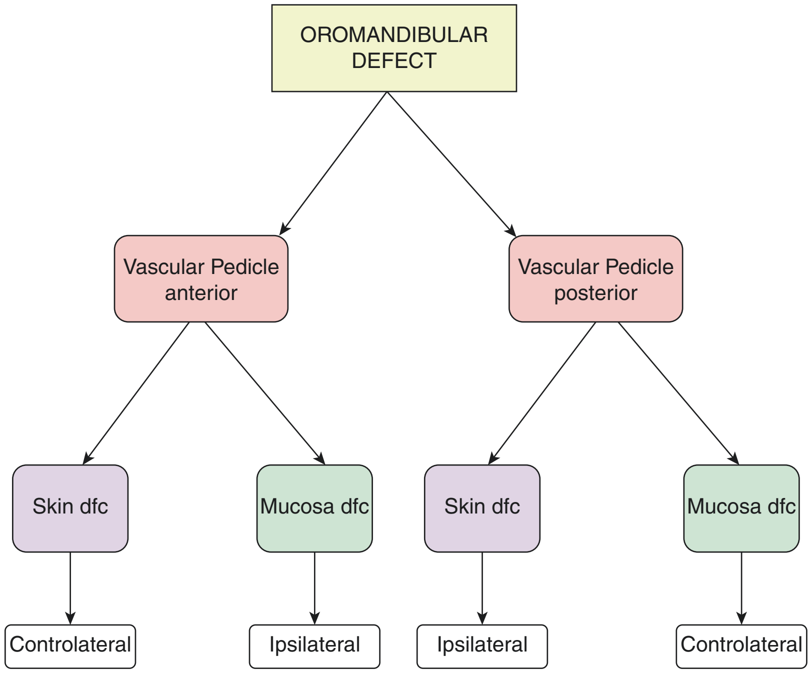


Fig. 13.2 Select donor site based on oromandibular defect and localization of the pedicle in the neck

Congenital anomaly or acquired disease of the trifurcation vessels is estimated to result in a dominant peroneal artery in 7–12% of the population. An uncommon but important anatomic variant is the arteria peronea magna (type III-C by Kim), a congenital anomaly in which the peroneal artery is the sole vessel to the foot, with patients having normal distal pulses and the absence of associated symptomatology. This condition has been described as occurring in 0.2–0.9% of the population [2].

In case of peronea magna or in a congenitally hypoplastic peroneal artery, fibula flap cannot be harvested in this side. Consider harvesting the controlateral side if no anatomical anomalies are present or evaluate a different flap [3].

13.2.2 Donor Site Selection

Fibula flap can be composed of only the bone component or osteofasciocutaneous.

The surgeon, according to the defect to be repaired, chooses the side from which to prepare the flap based on the following factors: exiting of donor vessels and positioning of the skin paddle. The flowchart summarizes the methods of choice (Fig. 13.2).

13.2.3 Flap Harvesting

13.2.3.1 Preoperative Management

It is essential to know if in the anamnesis the patient has vascular problems or previous traumatic fracture of the selected limb.

Pulsation of the posterior tibial artery, the peroneal artery, and the dorsalis pedis must be checked. An Allen test can be performed between dorsalis pedis and the posterior tibial arteries. Nowadays, CT angiography or MRI angiography is mandatory to detect vascular anatomy and anomalies that preclude blood supply in the foot after peroneal artery harvesting.

13.2.3.2 Patient Positioning

The leg should be positioned flexed at an angle between 45° and 90° and the foot resting on a sandbag or similar in order to ensure a stable support.

Perforating arteries must be sought preoperatively using Doppler probe. As reported in various

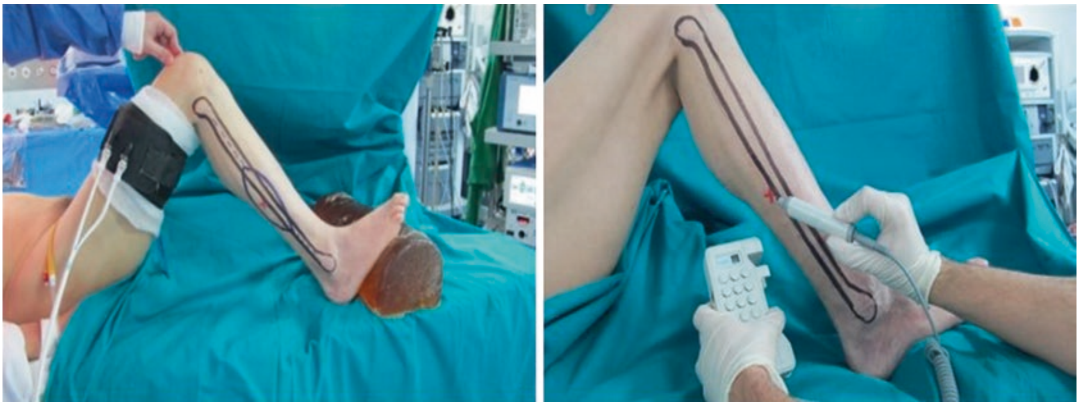


Fig. 13.3 Preoperative setting and doppler

studies, perforator vessels located in the lower two-thirds of the leg are usually septocutaneous. Those located in the upper portion of the leg are usually musculocutaneous. Once perforators are founded, they must be marked with a surgical pen (Fig. 13.3).

13.2.3.3 Flap Design

Mark the fibular from the head to the lateral malleolus. Digital palpation of the posterior ridge of the fibula is useful in order to identify and mark the bone and connect the extremity (Fig. 13.3).

The incision line should ideally travel the posterior intermuscular septum, starting 6–8 cm below the head of the fibula, to preserve the superficial peroneal nerve, and reaching 6 cm from the lateral malleolus to preserve the ankle and the knee stability. The skin paddle should be designed including cutaneous perforators previously highlighted with the Doppler. Its ideal shape is elliptical to favor closure by the first intention. Usually, a skin paddle up to 4 cm width can be closed primarily.

Use of the tourniquet is advisable to obtain a surgical field without bleeding during the dissection. An orthopedic cotton bandage proximally wraps leg to avoid the prolonged contact with the inflated tourniquet.

The cuff is secured around the limb proximal to the operative site. Pressure is exerted on the circumference of the leg by means of compressed gas, which is introduced by a microprocessor-controlled source, via connection tubing. When sufficient pressure is exerted, vessels and arteries beneath the cuff become temporarily occluded, preventing blood flow to pass the cuff. While the cuff is inflated, the tourniquet system automatically monitors and maintains the pressure chosen by the user (approximately 350 mmHg). Cuff pressure and inflation time are displayed, and an audiovisual alarm alert informs the user to alarm conditions, such as a cuff leak.

Pneumatic surgical tourniquet prevents blood flow to the low leg and enables the surgeon to work in a bloodless operative field. This allows flap harvesting to be performed with improved precision, safety, and speed.

Before the tourniquet inflation, moderate exsanguination of the limb is also recommended. An Eismarch bandage (a narrow elastic bandage 5–10 cm wide) is used to drain venous blood away from the leg (exsanguinate) before inflating the tourniquet. It is advisable a moderate exsanguination in order to permit the identification of septo-cutaneous perforator pedicles.

The acceptable range of tolerance to ischemia of the leg remains controversial (Fig. 13.4).

13.3 Osteocutaneous Flap: Surgical Steps

We describe the lateral approach to harvesting the fibula flap.

Fig. 13.4 Preoperative setting and tourniqut inflation

13.3.1 Step 1

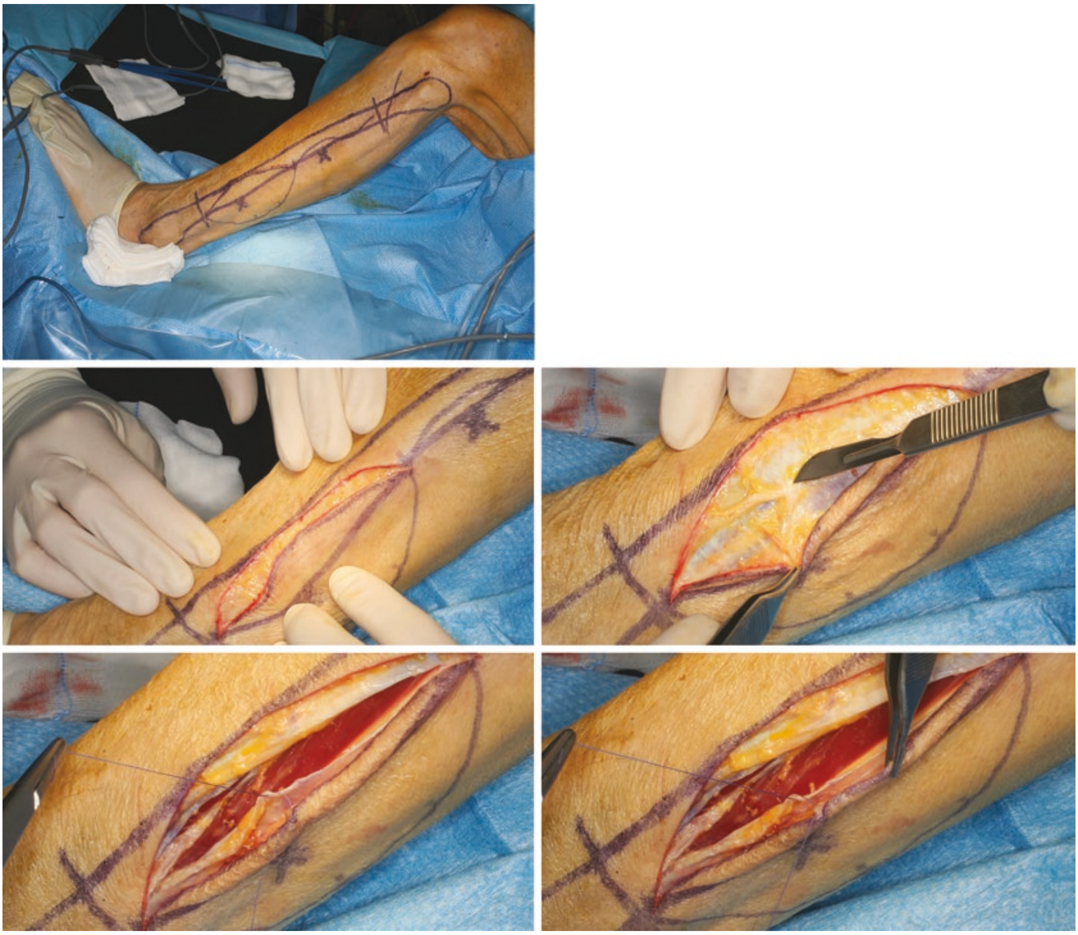
Incision is performed in the upper portion of the skin paddle with a cold scalpel and must include the dermis and underlying adipose tissue until it reaches the fascial layer that is also delicately incised. The upper incision line is made wider than that of the drawn edge, to be subsequently compensated by the lower one. Identify the tendon of the peroneus longus muscle. In this phase, it is useful to place some resorbable stitches to consolidate the subcutis with the fascia. Usually, 3–4 nodes are sufficient (Figs. 13.5 and 13.6).

13.3.2 Step 2

After identifying the peroneus longus muscle, continue with the delicate detachment of the skin paddle until the muscular septum is identified. This maneuver can be done using the scalpel handle, Stevens' scissors, or finger blunt dissection, pressing the underlying muscle until the skin perforators that cross the posterior intermuscular septum are identified. The position of the perforators corresponds to that of the previously marked Doppler point. It is important to note that if the cutaneous perforators are born anterior to the septum they can originate from the anterior tibial artery, and therefore, they cannot be harvested with the skin paddle (Figs. 13.7 and 13.8).

13.3.3 Step 3

Subfascial incision is continued superiorly and inferiorly identifying the lateral muscular compartment composed of peroneus longus and brevis muscles. This compartment will be traction anteriorly, dissecting it from the fibula bone, until identifying the anterior intermuscular septum. Pay attention not to confuse anterior intermuscular septum with interosseous membrane. It is important not to perform a subperiosteal dissection of the muscles, but rather to



Figs. 13.5 and 13.6 Step 1: Skin and fascia incision

leave in place 1–2 mm of muscles layer in order to maintain the periosteal blood supply (Fig. 13.9).

13.3.4 Step 4

The anterior intermuscular septum is sectioned with cold scalpel to expose the extensor digitorum longus muscle and extensor hallucis longus muscle. These muscles represent the anterior protection of the anterior tibial vascular-nervous pedicle. Muscles should be gently dissected until the anterior tibial artery and veins and deep peroneal nerve are identified (Fig. 13.10).

13.3.5 Step 5

Once the muscles of the anterior compartment are dissected, we find posteriorly the interosseous membrane covering the deep muscular compartment (Fig. 13.11).

13.3.6 Step 6

The periosteum that covers osteotomy's area must be cut off for approximately 5 mm cranially and caudally. Superior and inferior incision lines are marked on the bone surface using pencil or monopolar scalpel. At this point, a periosteal dissector is used to create a 360° tunnel around the fibular bone in order to protect the vascular pedicle during osteotomy (Fig. 13.12).

The osteotomy can be done with an oscillating saw. Nowadays, we prefer the use of piezosurgery, which allows a better protection of the underlying soft tissues and pedicle. It is still of paramount importance to protect the pedicle with periosteal dissector or Oman (Fig. 13.13).

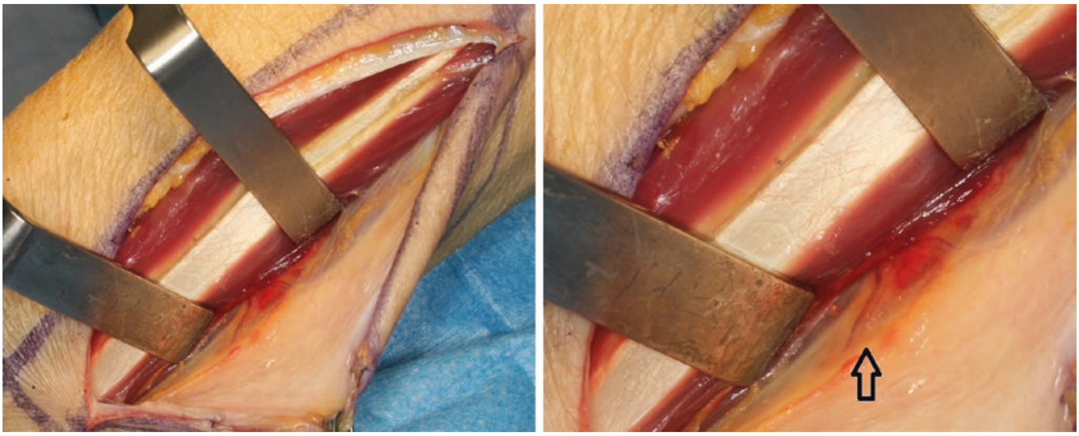


Fig. 13.7 Step 2: Identification of peroneus longus tendon and perforator vessels

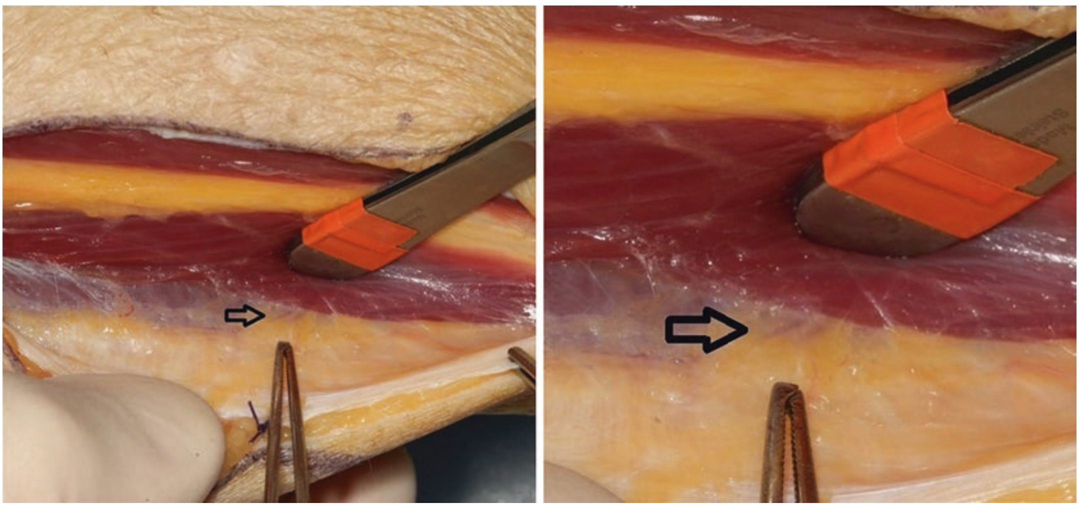


Fig. 13.8 Step 2: Identification of perforator vessels

13.3.7 Step 7

By tractioning the dissected fibula with bone Kocher forceps, the interosseous membrane is incised along the entire fibula. This maneuver allows fibula to be better laterally retracted. Below the interosseous membrane, we find the posterior tibial muscle and below it the peroneal pedicle composed by artery and veins. The pedicle should be identified at the level of inferior osteotomy, ligated, and cut. It is easily found because it runs in an oblique position in a caudo-cranial direction (Figs. 13.14 and 13.15).

13.3.8 Step 9

Once the vascular pedicle has been identified, the posterior portion of the skin paddle can be incised. Resorbable stitches between subcutaneous tissue and fascia are positioned in the same manner of anterior incision. A dissection is carried out, including the fascia, and it is modulated on the actual location of the perforator vessel. To protect perforator vessel, a cuff of soleus muscle can be included in the flap (Fig. 13.16).

Fig. 13.9 Step 3: Detachment of lateral muscles from fibula bone

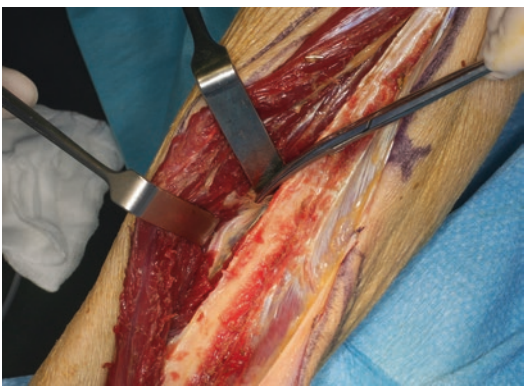


Fig. 13.10 Step 4: Section of the anterior intermuscolar septum and identification of anterior tibial pedicle

13.3.9 Step 10

The pedicle is gently discovered sectioning the posterior tibial muscle while performing a gentle lateral traction on the fibula. This muscle presents a characteristic orientation of muscle fibers (chevron oriented). This maneuver can be performed both with blunt dissection with the finger or with a bevel tool, lifting the fibers upward and then cutting them with the electric scalpel.

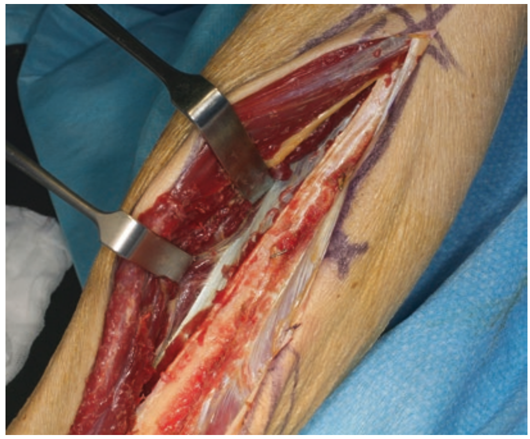


Fig. 13.11 Step 5: Interosseous membrane is detatched

The same procedure is repeated for the dissection of the flexor hallucis longus muscle, posterior to the pedicle. The two muscles envelop the vessels of the flap.

The dissection must be at least 1 cm from the fibula to avoid traumatic lesions of the vascular pedicle (Fig. 13.17).

13.3.10 Step 11

The osteocutaneous fibula is progressively detached from the distal to the proximal region. The skin paddle must be protected from falling down with a hand or suturing it to the bone (Fig. 13.18).

13.3.11 Step 12

Peroneal vascular system is isolated and followed until it enters the posterior tibial pedicle. It is important to consider that the direction of the pedicle tends to medialize, moving toward the confluence, so the dissection must be performed carefully in the cranial part. A sharp dissection between peroneal vessels and tibial nerve (i.e., the more lateral structure of the posterior tibial pedicle) in this point is useful to gain 1–2 cm length of pedicle (Fig. 13.19).

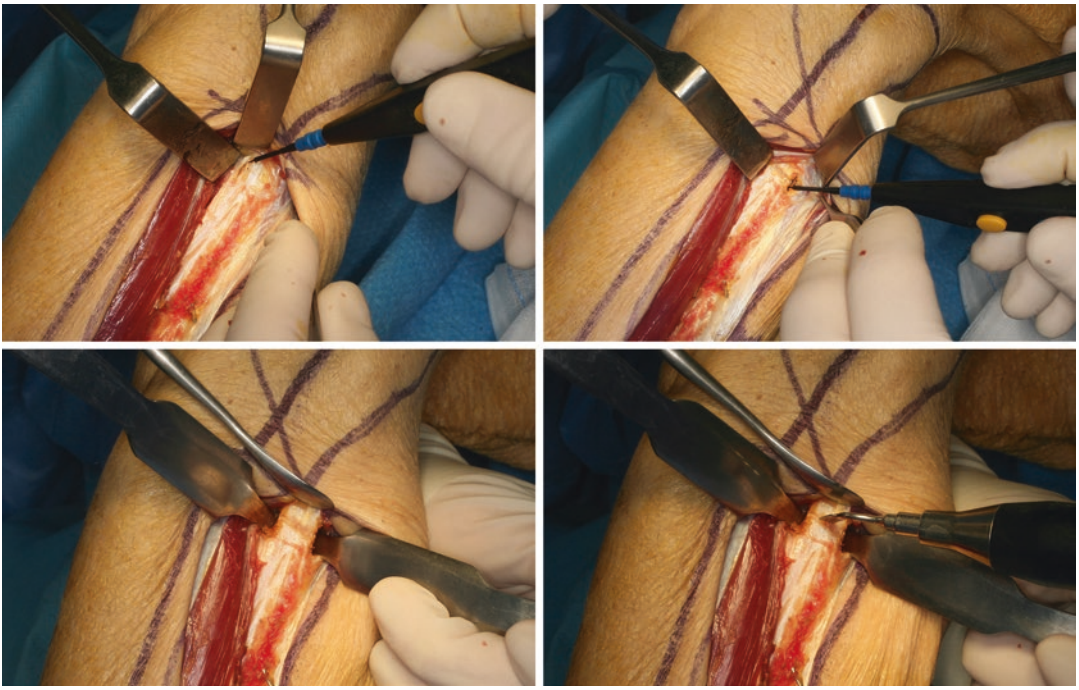


Fig. 13.12 Step 6: Osteotomy lines are marked and 360° tunnel around fibula bone are created before osteotomy

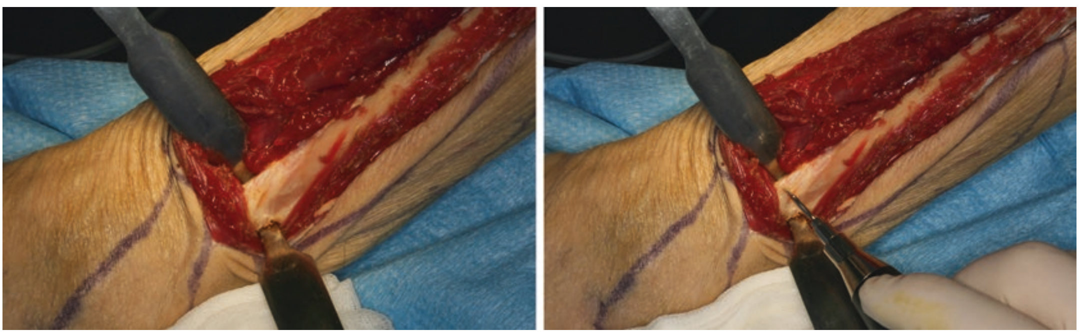


Fig. 13.13 Step 6: Distal and proximal osteotomies are performed

13.3.12 Step 13

Once the confluence has been identified and well dissected, the tourniquet is deflated and the perfusion of the flap is checked, highlighted by bleeding at the level of the distal medulla and of the skin paddle. Before releasing the tourniquet, it is important to inform anesthesiologist in the room because the patient can experience temporary hypotension. Cover the flap with gauzes soaked with warm water. Before cutting the pedicle, it is important to check for any bleeding in the muscles. When recipient site is ready, peroneal pedicle can be ligated, avoiding damage to the posterior tibial artery and nerve (Fig. 13.20).

13.3.13 Step 14

Checking of hemostasis, reposition of the remaining muscles, and subsequent closure of the donor site is performed. One or two suction drains are placed, and they can be removed after 3 days. If the closure by the first intention is too tight, we suggest to use a skin graft to cover skin defect (Fig. 13.21).

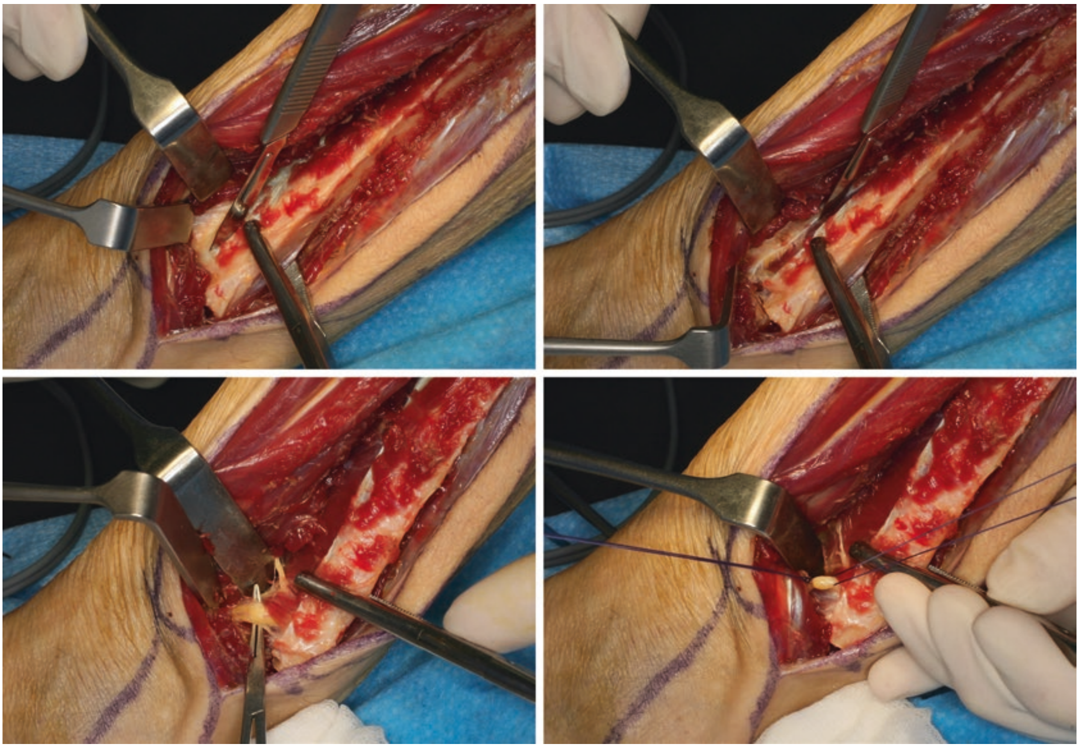


Fig. 13.14 Step 7: Distal identification of peroneal pedicle

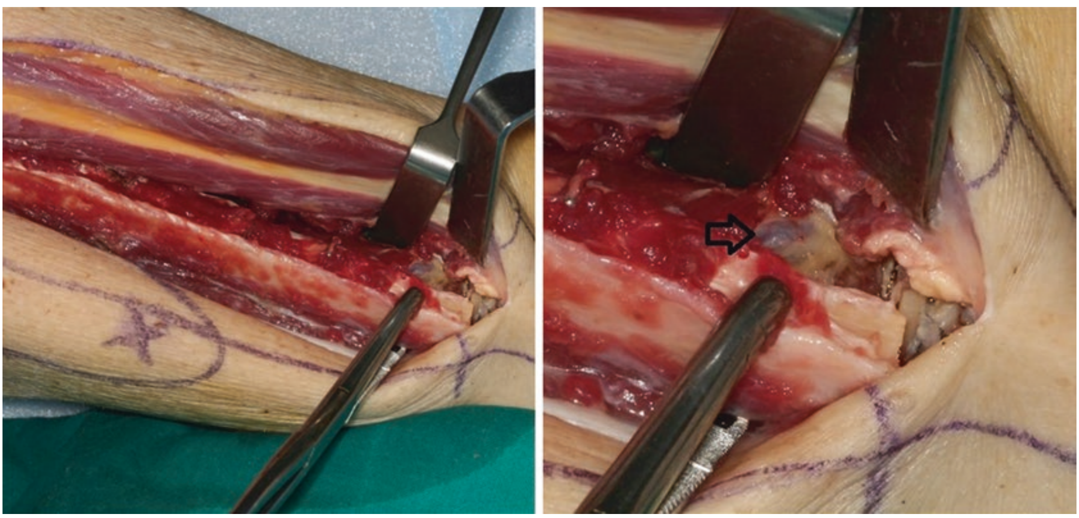


Fig. 13.15 Step 7: Distal identification of peroneal pedicle

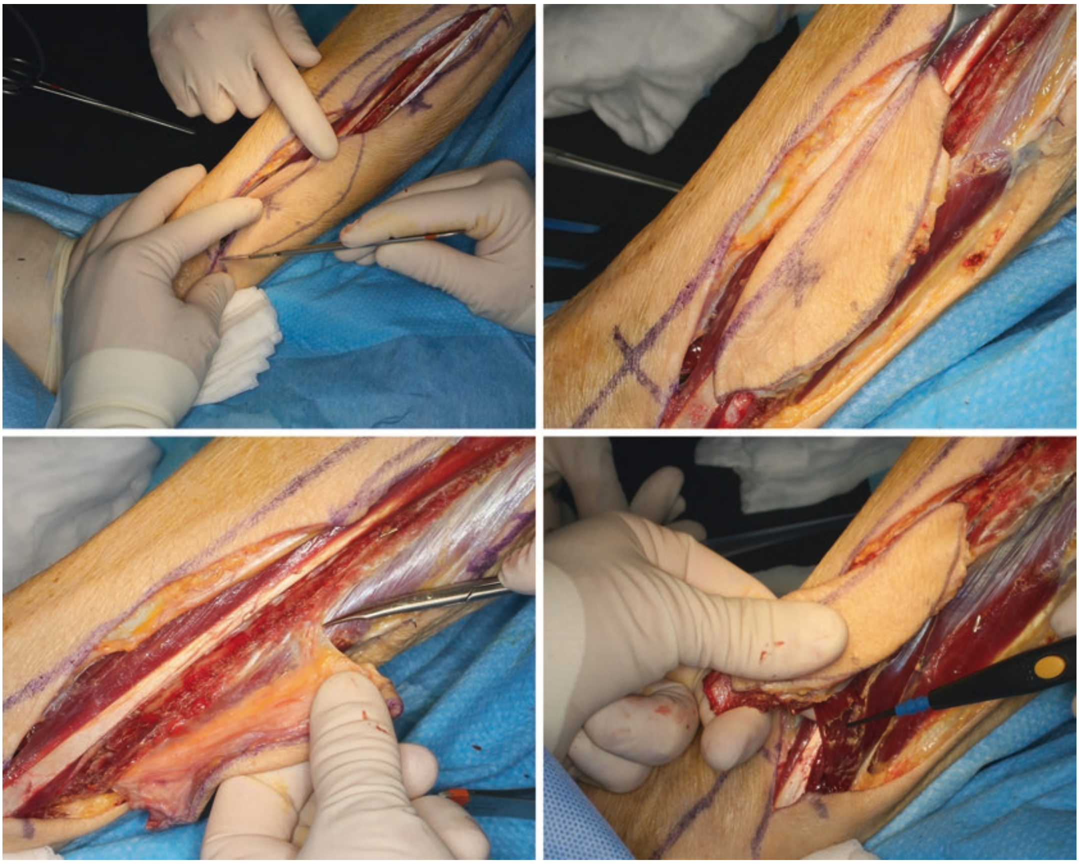


Fig. 13.16 Step 9: Posterior skin paddle incision and soleus cuff section

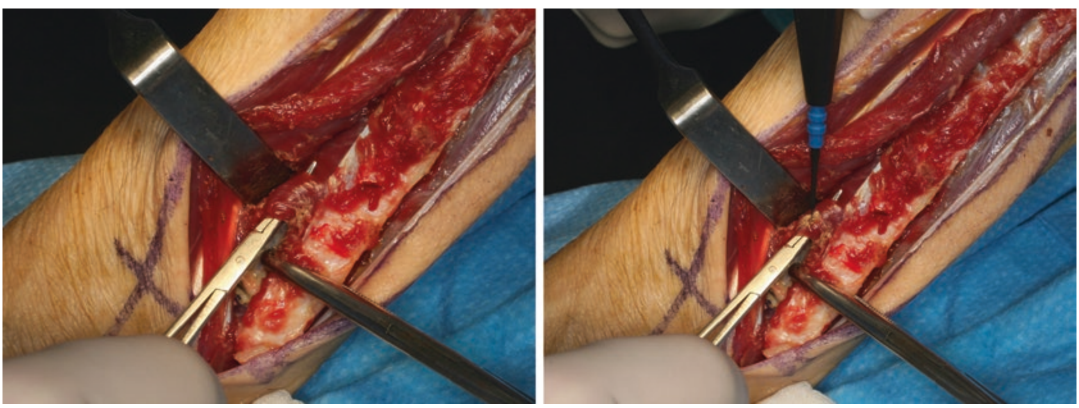


Fig. 13.17 Step 10: Pedicle is isolated sectioning posterior tibial muscle and flexor hallucis longus muscle

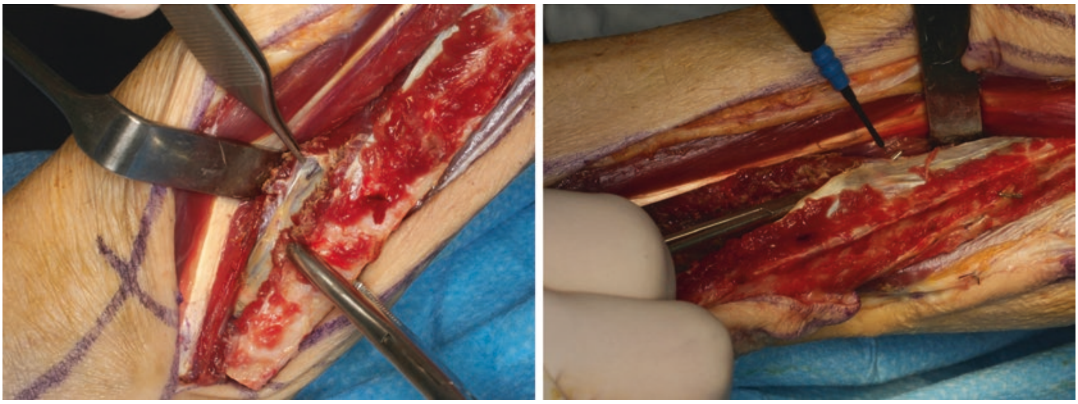


Fig. 13.17 (continued)

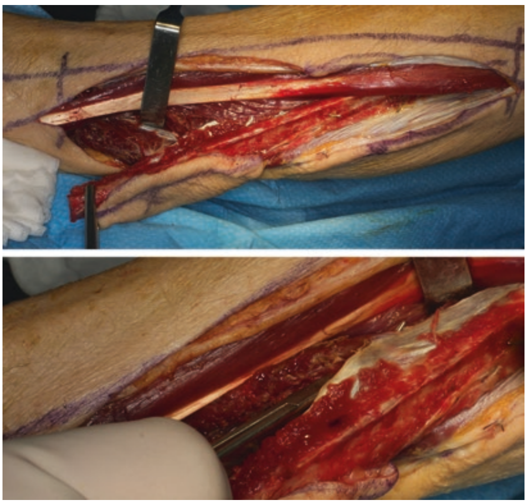


Fig. 13.18 Step 11: Flap is raised from distal to proximal

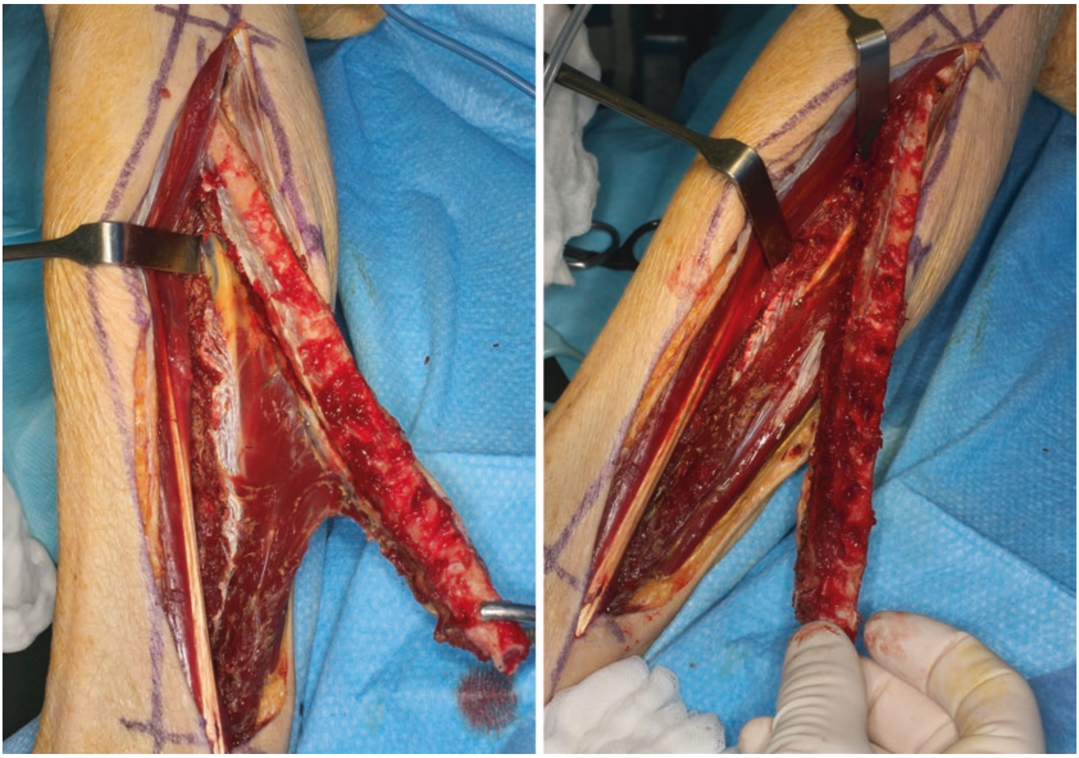


Fig. 13.19 Step 12: Confluence of peroneal pedicle into the posterior tibial pedicle must be carefully detatched and dissected

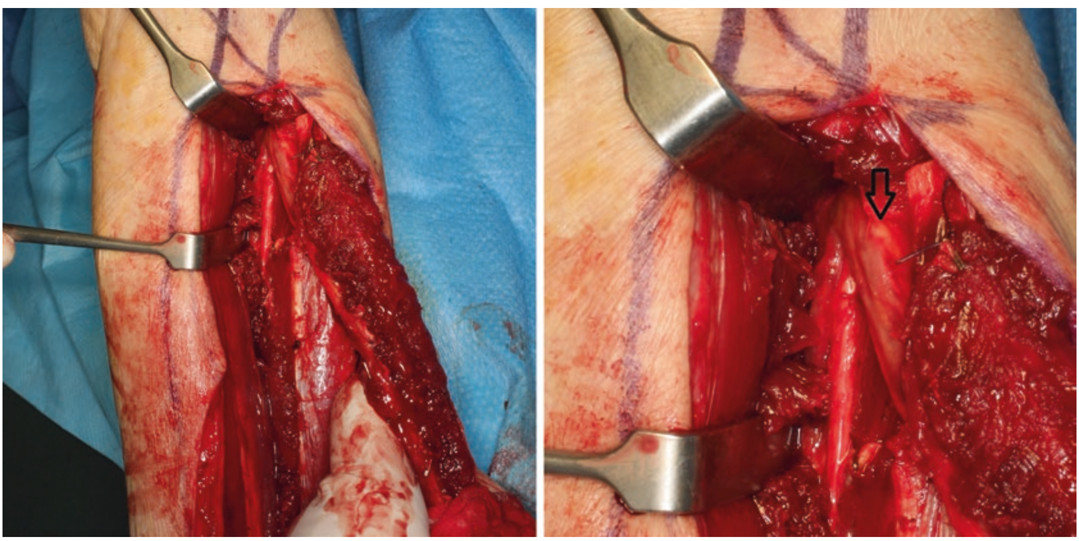


Fig. 13.20 Step 13: Revascularization of the leg

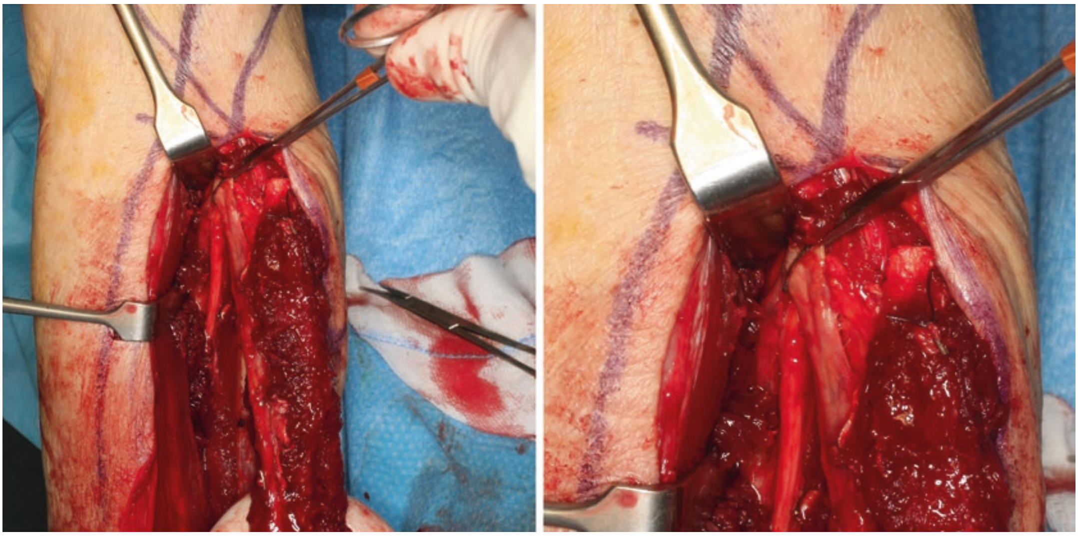


Fig. 13.20 (continued)

Fig. 13.21 Step 14: Donor site closure

13.3.14 Final Appearance of the Harvested Flap (Fig. 13.22)

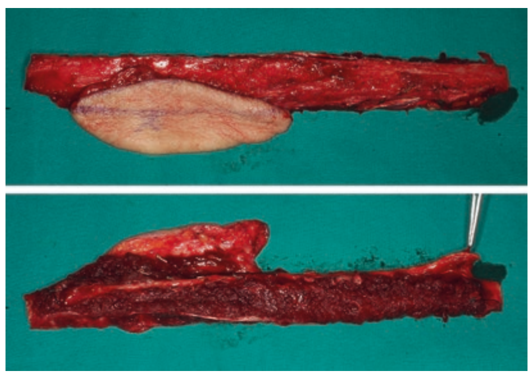


Fig. 13.22 Final appearance of the flap

References

1. Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. Ann Surg. 1989;210:776–81.
2. Disa JJ, Cordeiro PG. The current role of preoperative arteriography in fibula free flaps. Plast Reconstr Surg. 1998;102:1083–8.
3. Lohan DG, Tomasian A, Krishnam M, Jonnala P, Blackwell KE, Finn JP. MR angiography of lower extremities at 3 T: presurgical planning of fibular free flap transfer for facial reconstruction. AJR Am J Roentgenol. 2008;190:770–6.

Further Reading

Wei FC, Seah CS, Tsai YC, et al. Fibula osteoseptocutaneous flap for reconstruction of composite mandibular defects. Plast Reconstr Surg. 1994;93:294–304.

Wallace CG, Chang YM, Tsai CY, Wei FC. Harnessing the potential of the free fibula osteoseptocutaneous ap in mandible reconstruction. Plast Reconstr Surg. 2010;125:305–14.

Correction to: Anatomical Considerations of Free Flaps

L. Bianconi, L. Pierotello, G. Molteni, R. Pellini, and D. Marchioni

Correction to:
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***Free Flaps in Head and Neck Reconstruction*,**
https://doi.org/10.1007/978-3-030-29582-0_2

The original version of this book was revised to update the following correction

- The original Fig 2.5 has been swapped with 2.6.

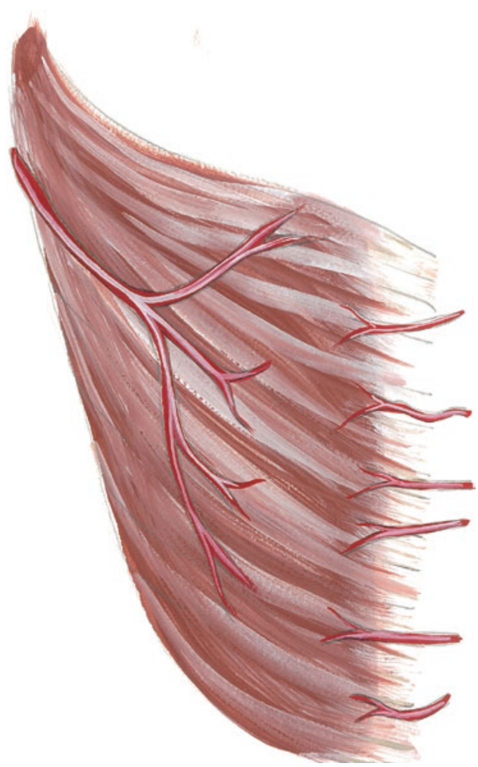

Fig. 2.5 Type 4. The latissimus dorsi muscle is supplied by two separate vascular systems. The main blood supply arises from the thoracodorsal artery via the subscapular artery. There is a secondary blood supply that arises from segmental perforating branches off of the intercostal and lumbar arteries

The updated online version of this chapter can be found at https://doi.org/10.1007/978-3-030-29582-0_2

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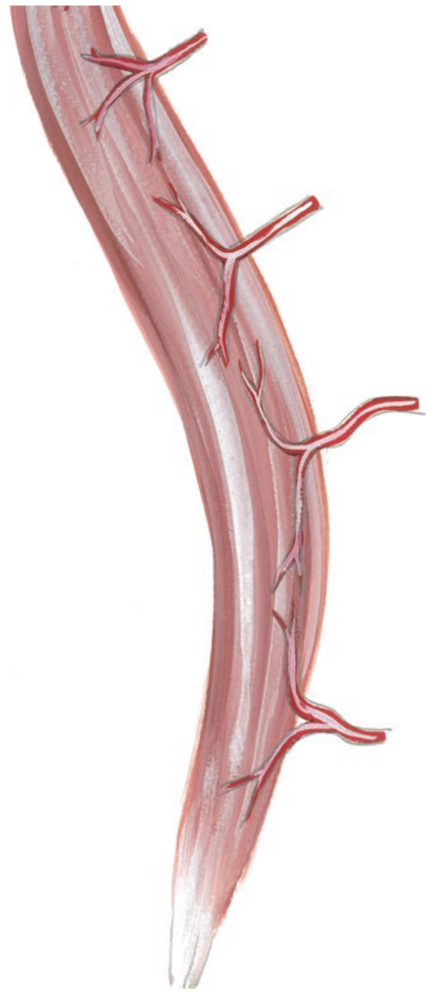

Fig. 2.6 Type 5. The sartorius muscle is supplied by multiple segmental pedicles. For each third of muscle, there is at least one vascular pedicle, often two pedicles, and occasionally three each arising from the superficial circumflex iliac artery, from the saphenous artery, or from the descending genicular artery