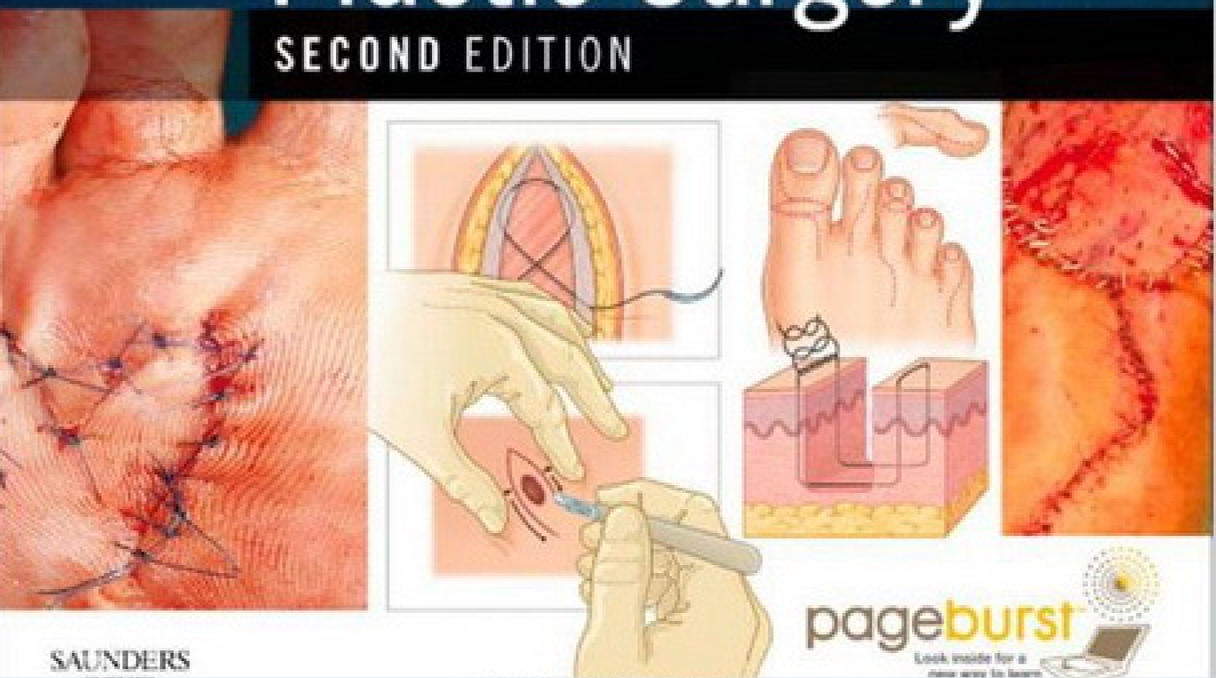
Foreword by **Mark Myerson**

Edited by
G. DOCK DOCKERY
MARY E. CRAWFORD

Lower Extremity Soft Tissue & Cutaneous Plastic Surgery

SECOND EDITION



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Lower Extremity Soft Tissue & Cutaneous Plastic Surgery

Second edition

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Foreword

Michael J. Coughlin

Lower Extremity Soft Tissue & Cutaneous Plastic Surgery, second edition, is a thorough review of the principles of operative intervention of the lower extremity. Editors, G. Dock Dockery, DPM and Mary E. Crawford, DPM have completely updated this textbook, but have retained the thoughtful approach used in the prior edition, to patient evaluation and treatment with a special emphasis on the anatomy of the foot and ankle, and specific surgical techniques for skin grafts, flaps and soft tissue coverage. These techniques whether used in a primary operative procedure, or in the case of a revision surgery are explained in a very understandable fashion using both simple drawings and intraoperative photographs.

I found the principles elaborated for surgical instrumentation, dressings, and techniques were applicable for the student and resident in training; the flaps and soft tissue sections, I believe, are advantageous for the surgeon in practice as well. In many cases, these techniques receive little attention in routine podiatric and orthopedic training, and this textbook fills a noted void in this area of education.

In all cases, the techniques are discussed, illustrated, and explained in a fashion that is simple and straightforward, making it an excellent reference textbook for not only the podiatric and orthopedic surgeon, but for anyone dealing with complex surgical coverage issues.

I found this to be a delightful contribution to our foot and ankle literature, and the step-by-step manner in which different procedures are explained, makes it so incredibly easy to read and to understand. I highly recommend it as a primary reference source for all foot and ankle surgeons.

Michael J. Coughlin, MD

Foreword

Sigvard T. Hansen Jr.

I am very pleased to have been asked to write a foreword for the second edition of this book edited by Drs. Dockery and Crawford. I have practiced foot and ankle surgery in the same community with these authors and have long recognized that they have special interests and skills in this area and in these topics.

The fine points of cutaneous diagnosis and treatment are not of foremost interest to most foot and ankle surgeons, particularly those who are orthopedically trained. Our skills are focused more on the musculoskeletal structures. Knowledge about the foot and ankle, as well as the levels of skill required to manage serious problems, have increased greatly both in orthopedic and podiatric groups in the past 30 years. Increased interaction between the two groups has helped fuel this growth, as each has much to offer the other.

Podiatry has long had a greater interest in the skills required to treat skin-related problems, which are a major part of foot and ankle care. As noted in this book, the number of diabetic patients is projected to markedly increase in the near future. These skills will become even more important, as larger numbers of patients with numerous skin and digit-related problems present for treatment.

A potential problem with both orthopedic and podiatric practitioners is the tendency to get overly excited about major new reconstruction options and implants and never really adequately learn, or just ignore, the very important basic principles and techniques of managing skin wounds. This book can help remedy that problem. The second edition has been significantly improved over the first with more extensive illustrations, references and added detail. Additional chapters, some written by MD plastic surgeons and dermatologists, expand the book's scope and sophistication.

I would recommend this as required reading for all surgeons doing any level of work in the foot and ankle area. I believe it should be recommended, if not required, reading in training programs in the foot and ankle, possibly even in plastic surgery.

Sigvard T. Hansen, Jr., MD

Preface

As with the first edition, this edition of *Lower Extremity Soft Tissue & Cutaneous Plastic Surgery* is intended to provide a comprehensive and practical manual of the most commonly performed lower extremity soft tissue and cutaneous surgical procedures. The text moves from basic, but very important, information to complex cutaneous techniques and reconstructive surgeries. The process starts with preoperative considerations, cutaneous and microvascular anatomy, instrumentation and tissue handling, and works its way through anesthesia, hemostasis and suture materials, wound-healing properties and techniques. Next, attention is directed toward understanding and utilizing medical photography and, finally, into the heart of the subject with specific procedures, each chapter illustrated with color photography and beautiful drawings.

There has been a tremendous increase in the scope and complexity of cutaneous surgical procedures performed by lower extremity surgeons in the past two decades. This is partly due to increased patient acceptance of outpatient skin procedures, along with the continued attainment of precise knowledge and skills in reconstructive and plastic surgery techniques by all physician specialists. Additionally, there has been an increase in the cooperative relationships and referral patterns among plastic surgeons, dermatologic surgeons, podiatric foot and ankle surgeons, surgical oncologists, orthopedic surgeons and general practitioners. This process has helped to promote the sharing of knowledge, training, and information regarding the performance of simple and complex cutaneous procedures for the lower extremities.

The ultimate goal is to allow the reader the ability to develop increased self-confidence in approaching lower extremity cutaneous problems. This book is designed to be thorough in scope by providing specific and practical information for both the new cutaneous surgeon and the more experienced practitioner.

G. Dock Dockery DPM FACFAS
Mary E. Crawford DPM FACFAS
Seattle, 2012

Abbreviations

ADM – abductor digiti minimi
AHB – abductor hallucis brevis
AHL – abductor hallucis longus
APTT – activated, partial thromboplastin time
CAT – computerized axial tomography
CCD – charge-coupled device
CHF – congestive heart failure
CT – computerized tomography
DIC – disseminated intravascular coagulation
DTM – dermatophyte test medium
EDB – extensor digitorum brevis
EDL – extensor digitorum longus
EHL – extensor hallucis longus
FDB – flexor digitorum brevis
FDL – flexor digitorum longus
FDM – flexor digiti minimi
FHB – flexor hallucis brevis
FHL – flexor hallucis longus
H&E – hematoxylin and eosin
IPJ – interphalangeal joint
LEPS – lower extremity plastic surgery
LET – lidocaine, epinephrine and tetracaine
LME – lines of maximum extensibility
LMM – lines of minimal movement
MCT – medial calcaneal tubercle
MCTD – mixed connective tissue disease
MRI – magnetic resonance imaging
MTPJ – metatarsophalangeal joint
NSAIDS – non-steroidal antiinflammatory drugs
PAS – periodic-Acid Schiff
PB – peroneus brevis
PVD – peripheral vascular disease
PVNS – pigmented villonodular synovitis
PVNT – pigmented villonodular tenosynovitis
RSTL – relaxed skin tension lines
SCC – subcuticular closure
SFA – superficial femoral artery
SLE – systemic lupus erythematosus
SLR – single lens reflex
SWC – standard wound closure
TA – tissue adhesives
TAC – tetracaine, adrenaline or epinephrine and cocaine
TMA – transmetatarsal amputations
USP – United States Pharmacopeia

Introduction

G. Dock Dockery

WHO IS THIS BOOK FOR?

One of the first questions considered in this textbook is: 'Who is this book intended for?' Is it for the student? Is it better suited to the surgical resident? How about the new practitioner? Or, would it be suited to the skilled surgeon who has already established a busy and successful practice? The answer is that this book is designed for all of these doctors. There should be no concern as to whether or not the practitioner is a dermatologist, podiatrist, orthopedist, general practitioner or even a master plastic surgeon. The only concern is that the physician be authorized by education, training, licensing and privileges to be considered a qualified medical provider to perform lower extremity soft tissue and cutaneous reconstructive and plastic surgery.

WHERE ARE THESE SURGERIES PERFORMED?

Some of the techniques that are outlined and detailed in this book are very simple procedures that can easily be performed in the practitioner's clinical setting. In this scenario, there is less formality in the preparation of the skin and surroundings. The skin may be washed and then cleansed with a quick-drying antiseptic, such as alcohol, except in cases where electrocautery procedures are being performed. The surgical area may then be surrounded with simple sterile drapes (either disposable or reusable) to provide a sterile field for the procedure. For some of the more involved techniques discussed, it might be more suitable to have the patient admitted to a surgery center or same-day-surgery unit at the hospital. In this case, the use of anesthesia, better-equipped surgical theaters, sterile surroundings and assistance may be extremely beneficial to both the patient and the surgeon. Obviously, the more complex and involved reconstructive procedures require the most extensively prepared facilities and equipment. The location of the surgery is not nearly as important as is the perioperative preparation and consideration of all aspects of the procedure and the potential complications.

PRINCIPLES OF CUTANEOUS SURGERY

One of the major principles of cutaneous surgery is that care should be taken at all times to protect the patient from any harm, whether from the clinical or surgical environment, or from external or internal chemicals and medications. This principle is no different from those that have always governed good clinical practice. The surgeon and surgical staff should always be vigilant in the handling of the patient's tissue, fluids or blood, as well as the instruments that come into contact with these entities. There should be no difference in the handling of tissues in a patient with HIV infection or hepatitis compared with any other condition.

No matter how simple or how complex the procedure planned, the skin should be handled with the utmost respect and as gently as possible. In fact, it should be handled as little as possible. One of the early lessons learned is that living tissue is easily damaged with improper techniques. Even though normal healthy skin can recover from most injuries quickly, there is no need to do additional damage to the tissues by forceful manipulation with tissue forceps or with inappropriate pressure with tissue retractors. In fact, long-term retraction, electrocautery and excessive swabbing of the surgical wound should be avoided whenever practical. Dead spaces should be properly closed with as few sutures as possible. Incisions should be closed in layers and should never be closed under tension. Excessive compression or restrictive bandages should also be avoided in all cases.

By carefully reviewing the principles and techniques within this surgery text, the practitioner should be able to gain additional insight and understanding of specific procedures and options that will facilitate precision of the surgery and improve the ultimate outcome. The benefits offered herein should minimize the risk of complications while significantly improving the quality of patient care. This should always be our first and final goal for any treatment offered to the patient.

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Chapter | 1 |

Preoperative patient evaluation

G. Dock Dockery

CHAPTER CONTENTS

INTRODUCTION

The preoperative management of a patient with a surgical problem involves three parts: the diagnostic work-up, a preoperative evaluation and the preoperative preparation. The diagnostic work-up determines the cause and the extent of the patient's condition. The preoperative evaluation is a general assessment of the patient's health to identify operative risks that may influence the recovery period or, ultimately, alter the surgical plan. This evaluation includes an anesthesia plan that takes into consideration the patient's overall medical condition(s), the requirements of the surgical procedure and the patient's preferences.

Whether the planned cutaneous procedures are exceptionally minor or extremely complex, it is crucial to consider that each case is as important as the next. Because serious complications may occur at any time, it is necessary to be fully informed as to the exact nature of the patient's condition, general health status, mental status and allergies before entering into the treatment program. In order to be prepared, it is imperative to have obtained a thorough evaluation preoperatively. Some practitioners feel that this step is unnecessary, but let me assure you that having obtained this information early on will be important if a problem should arise.

Other essential considerations before surgery include determining if the patient completely understands the following: the proposed surgical procedures; the risk factors associated with the surgery; the necessary actions after surgery and the long-term expected results. It is important to ascertain, before commencing the surgery, if the patient has planned for the appropriate care and recovery time and does not plan to take an extended trip or return to work too soon. Equally crucial is the assurance that the surgeon will be available during the immediate postoperative recovery period or that a covering physician, familiar with the type of procedure performed, is accessible to the patient during this time. Finally, the surgeon can prepare the patient for the operation by reviewing the procedure, postoperative medications and immediate expectations following the surgery.

It is generally assumed that the patient is an established patient and has a complete chart with the general patient information form already filled out. However, if the patient is new, and the procedure is being performed on the first visit (usually not recommended unless the patient is referred by another physician specifically for the procedure or, the condition is urgent in nature), they should complete the general patient information sheet prior to being seen by the surgeon. This form generally contains all of the necessary information regarding the patient's name, address and contact numbers, and overall health status. There should also be a listing for a person to contact if there are any problems or an emergency arises.

In pediatric patients, a parent or a legal guardian must accompany the child and should always be present during the consultation and informed consent. If the child is of a relatively mature age, the child should be included in the discussion. The child's concerns and wishes should always be addressed directly and in a manner that is understandable. For younger patients, creating a child-friendly environment with toys and offering stickers or other rewards are helpful. Encourage the child to bring a favorite toy or personal stereo to the procedure.

SECOND OPINION

Once the initial discussion and recommendations for treatment have been completed, it might be advisable to offer the patient a choice of obtaining another opinion. They are encouraged to get a second surgical opinion if they need it for their insurance or if they have any questions or concerns about the proposed procedures. We have found that by offering the patient this choice, it appears to lessen their anxiety about whether or not they are making the right decision. When the patient does seek another opinion, we have found that almost all second opinion surgeons agreed with our diagnosis and planned treatment. This information is important to document into the patient chart prior to the surgery.

The easiest method of suggesting that the patient gets a second opinion is to have a preprinted form available. This form should list several surgeons in your general area that you are familiar with and that do similar types of surgery as you. It is a simple matter to circle one or two doctors on this form that you would recommend that the patient see for a surgical opinion. The doctor's full name, medical degrees, clinic's address and phone number should be listed. It is also advisable to list the address and phone number of the local medical association. Once again, this is reassuring for most patients because it is offered up front as a source of further information regarding the surgeon and the procedure being recommended.

INFORMED CONSENT

Once the decision has been made to proceed with surgery, it is necessary to obtain comprehensive informed consent. Informed consent is much more than just stating the name of the planned procedure and having the patient sign the appropriate form. It entails providing sufficient information about the nature of the condition, the potential options or alternative forms of treatment available, the possible risks or complications and the benefits of treatment. This information needs to be written in lay terminology, and should be clear and honest in its presentation. Everything that is discussed must also be on the printed informed consent form.

Patients given verbal warnings are less able to recall them than those receiving written information. Additionally, the surgeon should review the consent form with the patient, rather than delegating this duty to another member of staff. It is helpful if a family member is present to witness the consent form. Finally, the patient should be offered the opportunity to ask any questions or voice any concerns prior to signing the consent form.

Under the options that are discussed with the patient, it is important to explain that they have three choices available: (1) leave the problem alone with no further treatment provided; (2) attempt conservative treatment with physical therapy, medications, injections or other non-surgical choices; and (3) the surgical option as outlined in the consent. Each of these options also has potential risks and these can be briefly discussed. The risk of no further treatment is that the condition may worsen or, at least, not go away. The risks of conservative care might include the continuation of the problem, reaction to treatments or medications or worsening of the condition. The risks of the surgical procedure should be more specific and should always include the common complications that might occur as a direct result of this particular surgery.

The general risks of any surgery such as scarring, nerve damage (pain or numbness), infection, recurrence or worsening of the condition should be mentioned at this time. A brief discussion of the anesthesia that is being contemplated and its most common risks may also be provided at this time. For cases in which regional or general anesthesia is being considered, it is best to explain to the patient that a certified anesthesiologist or nurse anesthetist will review the anesthesia in great detail prior to the surgery. A very detailed account of this perioperative period does not significantly increase patient anxiety and has the advantage of allowing patients a fully informed choice before they sign the consent form for surgery.

Once the informed consent has been discussed with the patient and there are no further questions or concerns, it is wise to dictate an extensive progress note for the patient's chart that clearly outlines the information that has been given to the patient. At no point should there be any suggestion as to a guarantee of results or outcomes, as this will undoubtedly cause a dilemma later, if there should be unsatisfactory results.

This informed consent form may be very general (Fig. 1.1) or it may be specific for only one type of procedure. In other words, a form can be made-up for each individual procedure, e.g. the rotational flap, showing the fine points of how it is performed, with drawings or illustrations outlining the details. Utilizing line drawings representing the foot or lower extremity, where the surgeon can draw the procedure onto it, is extremely helpful in showing the patient the actual procedure planned and providing a complete understanding of the proposed surgery (Fig. 1.2).

There is no strict outline that can be followed because of the multiplicity of treatment options and the diversity of patients. Aesthetic surgery, cutaneous lesion excision and major reconstructive soft tissue surgery, for example, all differ in patient expectations, preoperative assessments required and postoperative follow-up. The more urgent the treatment, the less detailed the information needed. In contrast, the more cosmetic the procedure, the more detailed the amount of information necessary regarding possible risks and expected outcomes. However, the guidelines reviewed earlier are basic to all preoperative informed consents and are designed to increase the patient's understanding of the expectations and to explain the risks involved.

Preoperative photographs are very helpful for providing additional documentation of the pathology present and the extent of planning by the surgeon. Each photograph should be clearly marked with the date the photograph was taken and the patient's information. It is even considered superior evidence if the patient has signed and dated the photographs or a form indicating that the photos have been taken. Patients will frequently forget what the original condition or problem looked like and the preoperative photograph is an excellent reminder for them. Furthermore, the preoperative photograph of a tissue lesion may be very helpful for the dermatopathologist during the histologic review of a biopsy specimen. Additional information regarding clinical photography is reviewed in Chapter 9.

PATIENT EXAMINATION

This part of the patient information provides the most help when general health issues and medicolegal situations arise. For this reason, special attention must be given to obtaining all of the necessary information to complete this part accurately. The information provided from the history and physical examination should be easily found within the chart and, above all, be very legible.

History

The initial element of the patient examination is the past medical history. The health status and general information about the patient's history is usually obtained in a questionnaire or history form. A clear determination of the cutaneous or soft tissue problem, its duration, symptoms and exact location, and any prior treatment, should be obtained at this time. Any known allergies to topical, systemic or environmental agents may be determined. Specific questions should include whether there are allergies to antibiotics, aspirin, latex, iodine, local anesthetic agents and tapes or adhesives. If an allergy exists, this information should be clearly printed on the front of the patient's chart and other forms and documented within the patient's chart records.

Also important is whether or not the patient is on any anticoagulants or agents such as aspirin, non-steroidal antiinflammatory drugs, immunosuppressive agents, beta blockers or vitamin E that may hinder normal coagulation and healing. Other related drug questions should include all drugs and medications that the patient may be taking, including those purchased without a prescription, such as vitamins, minerals, cold medications and herbal supplements. Specific questions should be asked about difficulties with normal healing, bleeding problems, excessive bruising following minor injuries or procedures, prior deep vein thrombosis, complications following any other surgeries and whether or not there were any past problems resulting from anesthesia.

It is essential to determine medical conditions such as diabetes, hypertension, heart or vascular disease, kidney disease, gastrointestinal disorders, liver conditions such as hepatitis and cirrhosis and glaucoma. Further information should include the use of alcohol and tobacco products and the exact daily use of these items. Patients may minimize this information and it is best to be very specific in the questioning and the reason why this information is important for the well-being of the patient.

Physical examination

The physical portion of the examination includes the vital signs: resting blood pressure, pulse rate, oral temperature and respiration rate. The vascular status and neurologic assessment are equally

Today's Date______________________Time:________________AM/PM

SPECIAL CONSENT TO OPERATE

PATIENT:____

I hereby authorize Dr.________________________________, and designated associates or assistants selected by said physician to perform upon me the following surgical procedure(s):

____

____

The purpose of the procedure(s) is to treat the following condition(s):

____

____

I consent to the performance of operations and procedures in addition to or different from those now contemplated, whether or not arising from presently unforeseen conditions, which the above-named doctor or his associates or assistants may consider necessary or advisable in the course of the operation.

I consent to the administration of such anesthetics as may be considered necessary or advisable by my doctor, anesthesiologist, or other qualified party under the direction of a physician.

For the purpose of advancing medical education, I consent to the admittance of observers, and/or the use of medical photography equipment in the operating room.

I consent to the disposal or pathology review of any tissues or parts, which may be removed.

I have not had any allergic reaction to any drug(s) except:

____.Initials_____

I understand and assume all risks, which may exist, as a result of my failure to disclose any medical condition(s) and/or previous or current use or abuse of alcohol or drugs to the above named physician and realize that this treatment plan could be affected with such an omission.

I recognize that throughout the course of treatment for my condition(s) I have the responsibility to follow and adhere to my doctor's instructions. Initials_____

A

Figure 1.1 Standard two-page consent form.

SPECIAL CONSENT TO OPERATE

ALTERNATIVE TREATMENTS:

___1. No further treatments provided/observation	___5. Medications
___2. Change in occupation or activities	___6. Padding/strapping
___3. Change of shoes/use of shoe inserts	___7. Injections
___4. Periodic care/Physical therapy	___8. Other: _______________

POSSIBLE RISKS INHERENT TO ANY SURGERY:

1. Infection and/or painful inflammation of tissues
2. Delayed or non-healing of incisions and/or operated bones
3. Excessive bleeding, swelling, and/or pain (complex regional pain syndrome)
4. Allergic reaction to suture or other implanted materials
5. Nerve or blood vessel complications (numbness, painful nerve, blood clots)
6. Over or under correction of the deformity
7. Loss of blood supply leading to amputation
8. Need for additional surgery or treatment in the future
9. General medical complications (reactions to anesthesia, loss of life, clot to lung)
10. Return of same condition or development of new problem

POSSIBLE RISKS SPECIFIC TO THIS SURGERY

1.____ Initials_____
2.____ Initials_____
3.____ Initials_____
4.____ Initials_____

PROGNOSIS:____

The nature and purpose of the operation, possible alternative methods of treatment, the risks involved, and the possibility of complications have been fully explained to me in a language in which I understand. **I acknowledge that no guarantees or assurances have been made as to the end results that may be obtained. Initials_____**

DO NOT SIGN THIS FORM UNLESS YOU FULLY UNDERSTAND EVERYTHING ON IT.

Patient Name (Print):____
Signature:________________________________ Today's Date:___________
(Patient or person authorized to consent for patient)
Relationship:____
Witness:________________________________ Date:___________
Physician:________________________________ Date:___________

B

Figure 1.1, Continued.

important and should be carefully measured prior to surgery. All patients undergoing surgery should routinely have this work-up performed. This information is essential in establishing the current patient health status and it may also expose some unknown primary medical condition that will require referral to the primary care provider.

The cutaneous condition should be re-examined, measured, photographed and documented in the chart during the physical examination. The extent of the proposed procedure may suggest the need for further diagnostic or preoperative laboratory evaluations, X-rays, magnetic resonance imaging (MRI) scans or special studies. In cases where there is a known preoperative medical condition or history of bleeding problems, it is advisable to obtain a complete blood count including: measurement of platelet count, a prothrombin time, INR (international normalized ratio) and partial thromboplastin time. With infected or ulcerated lesions a preoperative culture of the wound may be helpful in determining the source of the infection. It is usually not necessary to perform other laboratory evaluations before cutaneous surgery.

PATIENT PREPARATION

The overall preoperative assessment, including obtaining the medical history, performing the physical examination and completing the discussion of the informed consent, should be an opportunity to recognize possible mental or medical problems that can be dealt with prior to surgery rather than at the last minute. It is also a time where the diagnosis is confirmed and treatment approaches are fully reviewed

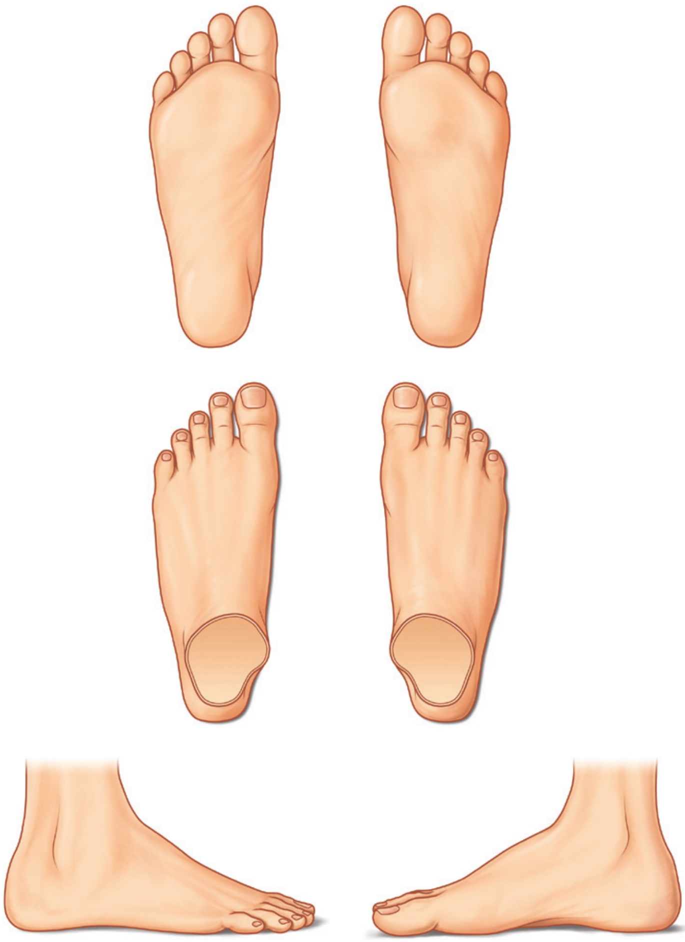

Figure 1.2 Drawing of the foot. Areas of concern may be circled or the proposed surgical procedures may be drawn onto the illustration. This will help the patient visualize placement of incisions and final scars.

and additional patient education is provided. This helps to build patient–surgeon rapport and trust, and ensures better outcomes for everyone involved.

Many minor procedures and most cutaneous surgery can easily be performed in the clinical setting. More complex cases are referred to the outpatient surgery suite or hospital operating suites. During the procedure, the patient is placed on the surgical chair or table in a comfortable position. The surgical site is prepared by washing any visible dirt with a detergent. The skin is then cleansed with a quick-drying antiseptic solution and the lesions are covered with sterile drapes. The surgical area should not be shaved unless absolutely necessary, as this increases the number of skin bacteria on the superficial skin surface. If the hair is simply in the way, it can be clipped back prior to the skin preparation. The skin may be prepared with chlorhexidine solution or 10% povidone-iodine surgical scrub solution. Prepackaged sterile fenestrated surgical drapes are very useful, but an appropriate-sized window can be cut into the center of a sterile disposable drape with the same result. Obviously, in more involved cases, the extent of skin preparation and draping is increased to suit the complexity of the surgery (See Chapter 7).

PATIENT EXPECTATIONS

The patient's expectations may vary considerably depending upon the nature of the condition that they present with. For example, a patient presenting with a minor cosmetic condition may have unrealistic comprehension as to the complexity of the treatment and may not understand that complications can occur in any case. It is imperative to look closely at the patient's psychological profile when dealing with worries about very negligible skin problems. Likewise, it is essential to be careful in the assessment of patients that are unhappy with previous surgical care or are obsessive or perfectionist in nature. These patients frequently have an unrealistic expectation and are more likely to be unhappy with the final results of surgery. In these examples, it might be advisable to make sure prior records are obtained, the patient has a second opinion and has discussed the potential risks and complications in some detail before proceeding with surgical scheduling.

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Chapter 2

Cutaneous anatomy and its surgical implications

Mary E. Crawford

CHAPTER CONTENTS

INTRODUCTION

The degree of complexity of the skin is often overlooked by the surgeon, but it plays an integral role in the postoperative healing, or non-healing, following any operative procedure. The intricate relationship between the layers that make up the epidermis and its relationship with the dermis create a complex physiological and biochemical organ system that serves many functions in the human body. The most obvious function of the skin is to serve as a protective barrier against microorganisms and harmful environmental elements entering into the more fragile internal organ systems.

The organization of the skin, however, also allows for water equilibrium, thermal regulation, protection from UV radiation, excretion, secretion, sensation of temperature and pressure or pain, as well as endocrine and immunological activities. To appreciate the mechanism by which the skin can perform these multiple functions, one must look more closely at the detailed organization of the epidermis, the dermis and the underlying support system of the subcutaneous tissue that makes up the complexity of the skin.

EPIDERMIS

The epidermis is a continuous, self-regenerating layer of stratified squamous epithelium that varies in thickness from 0.4 mm on the eyelid to 1.5 mm on the palms and soles. The epidermis is organized into four layers based on distinct structural features or unique functional activities. Each layer becomes more specialized as it ascends from the deepest to the most superficial layer. The epidermal layers, or strata, from deep to superficial are the stratum basalis (also called the stratum germinativum), stratum spinosum, stratum granulosum and the stratum corneum (Fig. 2.1). The final, most superficial layer of the stratum corneum is made up of the non-living, terminally differentiated keratinocytes, composed of a plasma membrane, filamentous and matrix proteins, and lipids.

The stratum basalis or stratum germinativum, the basal cell layer, is properly named, as the cells are mitotically active, self-regenerating progenitor cells present in the deepest layer of the epidermis and attached to the dermis at the level of the basement membrane. They are the least differentiated cells, capable of dividing rapidly, and as they advance towards the skin surface they begin the process of keratinization. The cells are attached by hemidesmosomes to the basement membrane aligned in a columnar fashion and the cell is dominated by an ovoid, deeply basophilic nucleus.

As the cells from the basal cell layer advance superiorly to the stratum spinosum, the cells take on the specialized task known as keratinization. This is the process by which the cells are committed to protein synthesis that forms keratin. The shape of the cell becomes altered and changes from the columnar cell of the basal layer to the prickle cell of the spinosum layer. The cell is flatter, more ovoid and begins to orient itself parallel to the most superficial surface as the cell matures and advances outward. Besides keratinization specialization, the spinous keratinocytes feature a potent lysosomal system for the degradation of any foreign material that may penetrate the outer layer. Lysozyme concentration is 5-fold higher in newborns compared with adults, which may contribute to the newborn infants' defence against invasive bacterial and other infections.

The final living layer of cells advancing towards the skin surface is the stratum granulosum. This layer, along with the stratum spinosum and germinativum, make up the living layers of the epidermis, known as the stratum Malpighii. The cells within the stratum granulosum are even more specialized than their precursors, with the cells containing a large number of granules full of keratohyalin. Keratohyalin is a protein precursor to filaggrin. Filaggrin stabilizes the epidermal structure by functioning as a glue or cement between the keratinocytes. The previously seen cellular elements such as the nucleus, mitochondria,

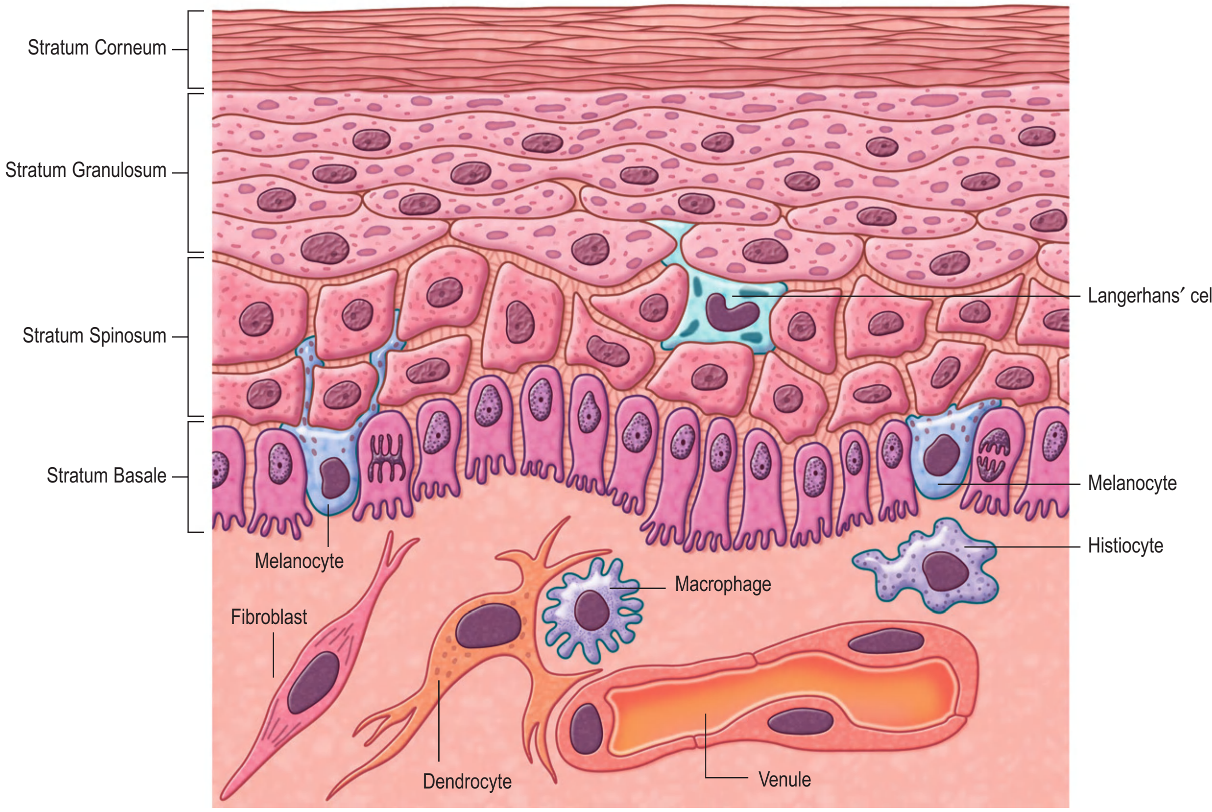

Figure 2.1 Cross-sectional drawing of the epidermis and its component layers.

Golgi apparatus, ribosomes and endoplasmic reticulum all undergo dissociation forming a homogenous, amorphous substance. As these cells advance to the surface, dehydration occurs and forms the stratum corneum.

As stated earlier, the stratum corneum is made up of dead, terminally differentiated keratinocytes that are flattened, polyhedral cells with absent nuclei. The cells interdigitate in a basket weave-like pattern to help prevent harmful environmental intrusion, but to also aid in resistance to water loss. This arrangement of cells allows for the orderly process of desquamation every 14 days. The lowest layer of the stratum corneum can be separated into a sublayer known as the stratum conjuctivum or lucidum. This layer is most pronounced on the palms and soles where the skin is most thick. This cell layer separates itself from the most superficial stratum corneum because of the presence of Odland bodies within the cells. Odland bodies contain a large amount of protein-bound lipids. The majority of the stratum corneum, however, is mostly characterized by cells whose contents are amorphous.

Specialized cells and appendages of the epidermis

Before advancing our attention to the dermal layer and its functions, it is important to discuss the specialized cells and the adnexa found in the epidermis. There are three specialized cells of neuroectodermal origin that are important in daily function of the skin: the melanocyte, the Langerhans' cell and the indeterminate cell. The melanocyte contains melanin granules giving color to keratinocytes and hair. The Langerhans' cells contain no melanin and are thought to be related to the monocytic cell with phagocytosis properties. The third cell type, the indeterminate cell, does not possess either melanosomes or Langerhans' granules and its function is not fully understood, however it may represent a population of stem cells capable of multiple differentiated lineages.

The adnexa, or specialized appendages of the epidermis, play a vital role in daily homeostasis. These highly specialized structures provide for regulation of temperature, evaporation and touch or pain stimulus. The adnexa of the epidermis begin their origin below the epidermis but travel through the epidermis to the surface and include the hair follicle, the apocrine and eccrine sweat glands, the sebaceous glands and the nerves of the epidermis. The hair follicle develops through an interaction between the epidermis and dermis and is highly sensitive to light touch.

The sweat glands, both apocrine and eccrine, are preoccupied with thermoregulation and evaporative heat loss and have both an intradermal and intraepidermal component. The apocrine gland is in greatest concentration in the axillae, anogenital and areolae areas and also produces a pheromone secretion. The eccrine gland is present overall in higher numbers but particularly in the axillae, the palms and soles, and plays a greater role in thermoregulation than the apocrine sweat gland. Sebaceous glands are found everywhere except the palms and soles, and are in very high concentration on the face and scalp. Sebum is the secretion from the sebaceous gland; it acts as a skin lubricant and contains lipid droplets and decomposing cell debris. This gland can be free standing or found in association with hair follicles.

As mentioned previously, the hair follicle can aid in light-touch perception, but additional sensation input from the environment is needed to adjust to ever-changing external stimuli. Free nerve endings are absent in the epidermis, but intraepidermal nerve endings do exist as Merkel-cell-neurite complexes. These complexes are terminal nerve branches from the dermis that reside just above the basement membrane on non-myelinated axon terminals and function as receptor cells of terminal nerve branching (Fig. 2.2).

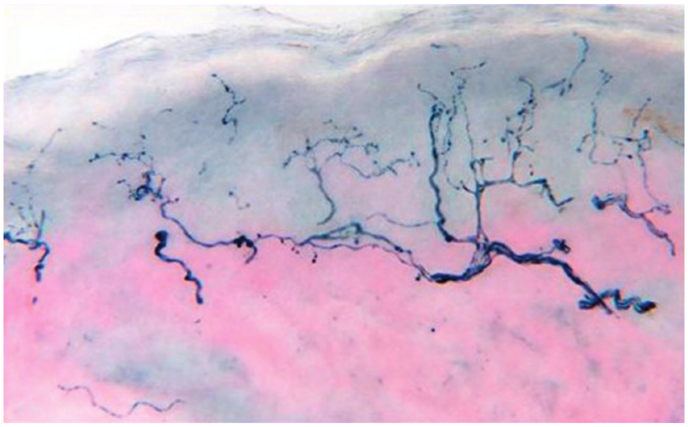

Figure 2.2 Magnification of terminal branches of epidermal nerve fibers. *(Courtesy of Dr Bradley Bakotic)*

DERMIS

The epidermis and dermis exist in a functional and morphological relationship and interact in exchanges of inductive biochemical relationships. This interaction is mediated across the epidermal–dermal junction or basement membrane. The basement membrane is a complex multilayer structure derived by substances contributed from both sections of the skin. While the epidermis is derived from the embryonic ectoderm, the dermis is derived from the embryonic mesoderm. The mesoderm gives rise to cells of the dermis, vascular elements, connective tissue stroma and subcutaneous tissue. As a composition generalization, the dermis is an intricate connective tissue network made up of collagen and elastic fibers embedded in a ground substance matrix that accommodates nerve bundles, sensory receptors and lymphatic and vascular elements. This structural composition assists in sensory perception, water homeostasis, temperature regulation and protection against mechanical trauma. When assessed in its entirety, the dermis is made up of 75% collagen. The two distinct layers of the dermis, the papillary and the reticular dermis, differ in the collagen matrix formed. The papillary dermis collagen is loosely arranged in a fine meshwork, while the reticular dermis collagen is assembled in thick interwoven bundles.

Elastic fibers then surround and border the collagen bundles and are distributed throughout the dermis, the walls of cutaneous blood vessels, sheaths of hair follicles and eccrine and apocrine sweat glands. The elastic fibers impart elasticity to these structures, allowing them to tolerate deforming forces without irreparable harm. Besides the collagen and elastic tissue, the connective tissue network is also composed of ground substance that supports the structural components of the dermis. Ground substance is a matrix that consists of glycosaminoglycans, such as hyaluronic acid, and glycoproteins, such as fibronectin, produced by fibroblasts. Fibronectin is important in wound healing and in forming matrix adhesions between collagen and elastin bundles, and between keratinocytes and the basement membrane.

The structural elements of the dermis differ either in cellular type or number, depending on the papillary or the reticular dermis. The papillary dermis is the region between the basement membrane and the subpapillary plexus in the reticular dermis. It is made up primarily of type III collagen in a loose network with large number of fibroblasts that have an increased proliferative and synthetic capability compared with fibroblasts of the reticular dermis. The papillary dermis interdigitates with papillae directly with the epidermis through the basal layer and is more vascularized than the reticularis by the subpapillary plexus, which extends a capillary loop into each papillae. The reticular dermis is the bulk of the dermis and extends from the subpapillary plexus to the hypodermis or subcutis. It is primarily composed of type I collagen with fibers arranged in large interwoven bundles surrounded by elastic fibers in a vast network. Veins, arteries and nerves occur as triads in the reticular dermis.

There are specialized cells that are indigenous to the dermis, including fibroblasts, macrophages and mast cells, while lymphocytes, plasma cells and leukocytes will migrate in response to chemical or mechanical stimuli. Although the cell types found in the papillary and reticular layers are similar, there appears to be a reduction in the number of cells seen in the reticularis. Fibroblasts are the principal cell type seen in the dermis and are responsible for the maintenance of the structural integrity of the dermis and vital to wound healing and scar formation. Fibroblasts synthesize the connective-tissue proteins in the dermis for collagen and elastin as well as the ground substance matrix proteins glycosaminoglycans and glycoproteins.

Macrophages are blood-borne monocytes that phagocytose foreign material or antigens and also play a vital role in wound healing. Mast cells are specialized secretory cells located primarily around the subpapillary plexus and also in the subcutaneous fat. The mast cells secrete substances that result in histamine release and vasodilatation. This attracts blood leukocytes with chemotaxis. Lysosomal granules of the mast cells are also capable of degradation due to the presence of acid hydrolases and other enzymes.

The final structural components of the dermis take into consideration the neural and vascular elements found in both the papillary and reticular dermis. The neural components involve both sensory and autonomic nerve structures. The autonomic nerve formation enervates blood vessels, arrector pili units and the apocrine and eccrine sweat glands. The sensory nerve units supply the hair follicles, mucocutaneous end organs, Meissner corpuscles and Vater–Pacini corpuscles. Lymphatic vessels are also prominent components of this system.

The cutaneous circulation is a complex array of subcutaneous and dermal vascular channels that supply nutrients and oxygen to both the epidermis and dermis. The circulatory system arises in the subcutaneous layer as a plexus of small arteries and veins. Small bundles of arterioles ascend from this plexus into the dermis. These small arterioles join with arteriole and venous capillaries and small postcapillary venules to form a plexus around eccrine and apocrine glands and hair follicles and the subpapillary dermis. Capillary loops then ascend from the subpapillary plexus to supply each dermal papilla, which then supplies the overlying epidermis (Fig. 2.3).

SUBCUTANEOUS LAYER

The structural and vascular support of the skin is derived from the underlying subcutaneous layer. This layer is comprised of adipocytes that synthesize large volumes of fat inside each adipocyte cell. These cells aggregate to form a primary microlobule that then aggregate again to form a secondary lobule about 1.0 cm in diameter. The vascularity within the subcutaneous layer involves a series of branching vessels to supply the overlying dermis and each secondary and primary microlobule.

Large blood vessels found in the major fibrous septa of the subcutaneous layer branch upward to supply the dermis, but no capillaries connect the dermis and the underlying subcutaneous fat. The subcutaneous fat is nourished by smaller vessels within the fibrous septa, giving rise to a complex network of capillaries between the arteriole and venule surrounding each lobule.

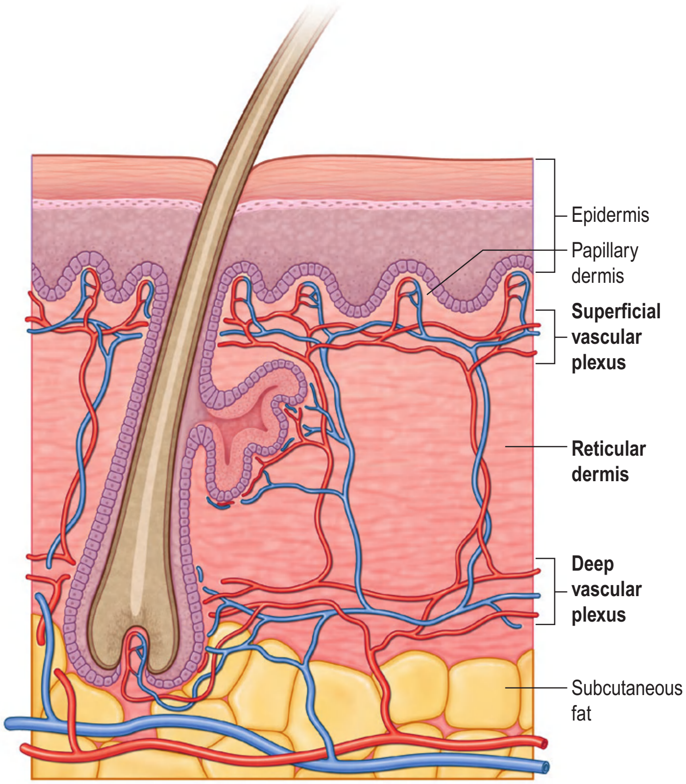

Figure 2.3 Drawing of the cutaneous vascular network demonstrating the relationship and connection of the deep and superficial vascular plexuses.

The subcutaneous layer plays additional vital roles in daily function. The deposits of fat act as shock absorbers, protecting and supporting vital organs. The adipose tissue also acts as an insulator for heat, and the metabolic burning of its stores of triglycerides serves as fuel for its thermogenic function. Energy is efficiently stored in the form of triglycerides and is released as fatty acids when necessary.

SURGICAL IMPLICATIONS

Understanding the complex morphological and biochemical composition of the epidermis and the dermis allows the surgeon to enhance surgical outcomes with fewer wound complications. Chapter 10 is entirely devoted to wound healing to demonstrate the significant role the skin plays in intraoperative and postoperative management. The ability of the skin to regenerate itself is at times nothing less than remarkable. The initial event in wound healing is hemorrhage followed by a clot of fibrin meshwork to establish hemostasis. A mitotic burst of the germinatival cells occurs at the periphery of the wound and becomes migratory as mitosis increases. So the cells may properly migrate, polymorphonuclear leukocytes and lymphocytes invade the wound in a predictable timed sequence and phagocytose and debride the wound.

The cells of the stratum germinativum continue migrating over the clot, until like cells are encountered and close the defect. Fibroblasts in the dermis synthesize a new matrix along with collagen, and elastin fibers and blood vessels reconstitute themselves by budding into the dermis. Any disruption of this sequence of events, whether mechanical or chemical disruption, will result in a delay or absence of wound healing and increased operative complications.

The vascular supply to the dermis is of critical importance to the surgeon during preoperative planning. The cutaneous vessels ultimately originate from named source vessels below. Each source vessel supplies a three-dimensional vascular territory of tissue from bone to skin termed an angiosome. Adjacent angiosomes form vascular connections between territories by way of reduced caliber (choke) vessels or similar caliber (true) vessels. The cutaneous vessels originate either directly from the source arteries or as terminal branches of muscular vessels. As these vessels traverse toward the skin, they form extensive subdermal and dermal plexuses. The dermis contains horizontally arranged superficial and deep plexuses, which are interconnected with communicating vessels oriented perpendicular to the skin surface. Cutaneous vessels ultimately anastomose with other cutaneous vessels to form a continuous vascular network within the skin. This extensive horizontal network of vessels allows for random skin-flap survival. The mapping of various angiosomes of the foot and leg will be discussed in later chapters pertaining to random skin-flap designs.

CONCLUSION

With the surgeon aware of the complexities of the skin and its surgical implications, many of the cutaneous surgical procedures can be undertaken with improved final outcomes and decreased complications. It behoves all surgeons to consider the intricate relationship of the skin and its components not only when performing any surgery, but in particular, when performing skin flaps and grafts. Evaluating the quality of the skin and determining the relaxed skin tension lines and the location of angiosomes will help the surgeon plan the procedure for optimal results.

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Chapter | 3 |

Vascular anatomy and its surgical implications

Andrew J. Meyr, John S. Steinberg, Christopher E. Attinger

CHAPTER CONTENTS

INTRODUCTION

Chapter 2 of this edition provided a comprehensive description of the structural anatomy of the skin and superficial fascia of the lower extremity. It is the intended emphasis of this chapter to build from that material and present a closer look at the vascular anatomy supplying these structures.

From a functional perspective, the vascular components of the cutaneous system are integral to its role in temperature maintenance, blood pressure regulation and immunological function. In addition, its role as part of the larger wound healing process has obvious implications that should be fully appreciated by all surgical specialties.[1–15] Though the vascular components are also required for the basic metabolic duties of the skin, these demands in fact only represent a small portion of the total potential cutaneous circulation.[1]

From a clinical anatomic perspective, the macrovascular supply to the lower extremity may best be appreciated in terms of the angiosomal and cutaneous circulations. The angiosomal circulation can be thought of as the named arteries that physically transport the blood into the foot and to the level of the deep fascia. The cutaneous circulation would then be comprised of the unnamed perforators and arterioles found within the superficial fascia and skin. These branches arise from the underlying named arteries of the angiosomal circulation. This cutaneous circulation therefore serves as a transition from the macrovascular supply of the angiosomes to the diffusion physiology of the capillaries and microcirculation.

All surgeons must possess an active awareness of the vascular supply to a given target tissue in the perioperative period. The physiology and pathophysiology of the angiosomal and cutaneous circulations should have an impact on the choice of procedure, incision planning and postoperative course.

ANGIOSOMAL CIRCULATION TO THE FOOT AND ANKLE

G. Ian Taylor first originated the concept of angiosomes in human anatomy to describe a three-dimensional block of tissue supplied by a single source artery incorporating all surgical layers including bone, muscle, fascia, subcutaneous tissue and skin.[1,2,16–19] Attinger and colleagues[20–22] further developed this principle with their work specifically examining the foot and ankle, eventually illustrating six foot angiosomes originating from three primary source arteries (Table 3.1). The concept of a single source artery supplying a unit of tissue is important when considering angiosomal principles of the lower extremity because this region represents a peninsular end-organ. All vascular supply to the foot and ankle enters through the popliteal fossa and the terminal branches of the popliteal artery: the anterior tibial, posterior tibial and peroneal arteries. In addition, there are anastomotic communications between these terminal branches within the foot and ankle, which gives the entire macrocirculation redundancy in case one of the named arteries is damaged or occluded.

Table 3.1 The angiosomes of the foot

Angiosome	Medial calcaneal	Medial plantar	Lateral plantar	Dorsalis pedis	Lateral calcaneal	Anterior perforating
Source artery	**Posterior tibial artery**	**Posterior tibial artery**	**Posterior tibial artery**	**Anterior tibial artery**	**Peroneal artery**	**Peroneal artery**
Boundaries	Posterior heel covering the Achilles tendon insertion.	Proximally to the junction of the heel and medial instep.	Proximally to the junction of the heel and lateral plantar midfoot.	Encompassing entire dorsal foot from the ankle joint to the forefoot.	Posterior heel covering the Achilles tendon insertion.	Encompassing a general area about the distal interosseous membrane and anterolateral ankle.
	Medial heel covering the area of the tarsal tunnel.	Medially to an arc 2–3 cm above the medial glabrous junction.	Medially to the midline of the plantar foot.	Medially to an arc 2–3 cm above the medial glabrous junction.	Entire plantar heel to the medial glabrous junction.	
	Entire plantar heel to the lateral glabrous junction.	Laterally to the midline of the plantar foot.	Laterally to the lateral glabrous junction.	Laterally to the lateral glabrous junction.	Lateral heel covering the area to the base of the fifth metatarsal.	
	Distally to the junction of the heel and medial instep.	Distally to the edge of the plantar forefoot.	Distally encompassing the entire forefoot.			

Posterior tibial artery angiosomes

The posterior tibial artery supports three angiosomes in the foot through its branches and terminal bifurcation: the medial calcaneal, medial plantar and lateral plantar arteries. Before terminal bifurcation however, the posterior tibial artery directly supplies the medial lower leg from the anterior crest of the tibia to the midline of the calf. The specific posterior border of this territory is represented by the central raphe of the Achilles tendon. Anterior and posterior branches bifurcate from five or six perforating arteries through the flexor hallucis longus muscle, soleus muscle or the intramuscular septum dividing the superficial and deep posterior compartments of the lower leg (Fig. 3.1).

Additionally, the posterior tibial artery supplies two important anastomotic connections before termination. The first is the posterior medial malleolar artery at the level of the medial malleolus. This branch directly anastomoses with the anterior medial malleolar artery, which is a branch of the anterior tibial artery. It provides direct communication between the posterior tibial and anterior tibial source arteries, in addition to supplying the tissue overlying the medial malleolus. The second important anastomoses are a series of communicating branches running proximal to the ankle joint and deep to the flexor hallucis longus that anastomose with similar communicating branches of the peroneal artery. These provide direct communication between the posterior tibial and peroneal source arteries, in addition to supplying the posterior perimalleolar area.

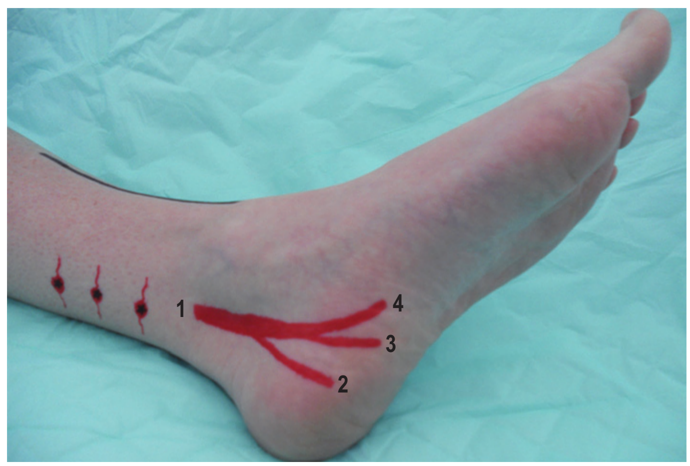

Figure 3.1 Posterior tibial artery angiosome. The posterior tibial artery (1) serves as the primary source artery for three angiosomes in the foot through its branches and terminal bifurcation: the medial calcaneal (2), lateral plantar (3) and medial plantar (4) arteries. Prior to terminal bifurcation, the posterior tibial artery directly supplies the medial lower leg from the anterior crest of the tibia to the midline of the calf. Anterior and posterior branches bifurcate from five or six perforating arteries (*) through the superficial and deep posterior compartments of the lower leg.

Medial calcaneal angiosome

The medial calcaneal artery branches from the posterior tibial artery proximal to the flexor retinaculum and supplies a region encompassing the entire plantar aspect of the heel (Fig. 3.2). To fully appreciate the breadth of this territory, the heel is divided into medial, posterior, lateral and plantar portions. The specific boundaries of this angiosome are from the posterior and medial heel (an area covering the Achilles tendon insertion and tarsal tunnel), across the entire plantar aspect of the heel to the lateral glabrous junction. This territory extends as far distally as the junction of the heel and medial instep.

Medial plantar angiosome

The posterior tibial artery then bifurcates into the medial plantar and lateral plantar arteries within the flexor retinaculum. The medial plantar artery supplies an angiosome encompassing the medial instep

Figure 3.2 Medial calcaneal angiosome. The primary source artery of the medial calcaneal angiosome (A) is the posterior tibial artery by way of the medial calcaneal artery branches (1). The boundaries of this angiosome are the posterior and medial heel (an area covering the Achilles tendon insertion and tarsal tunnel), across the entire plantar aspect of the heel to the lateral glabrous junction, and as far distally as the junction of the heel and medial instep.

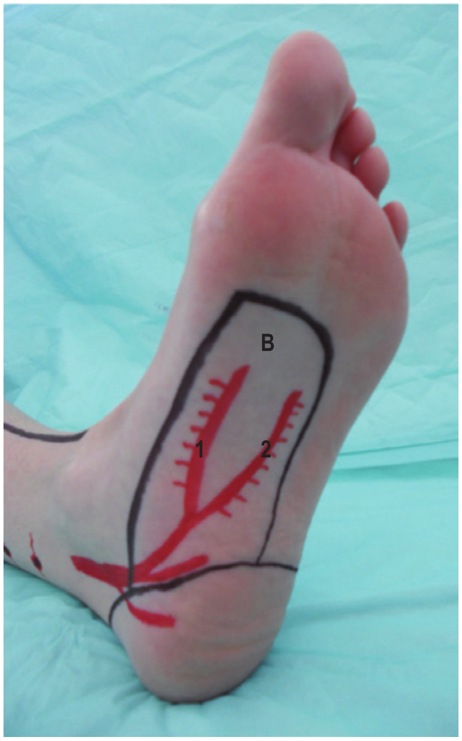

Figure 3.3 Medial plantar angiosome. The primary source artery of the medial plantar angiosome (B) is the posterior tibial artery by way of the superficial (1) and deep (2) branches of the medial plantar artery. The boundaries of this angiosome are the junction of the heel and medial instep proximally, the midline of the plantar foot laterally, an arc 2–3 cm above the medial glabrous junction medially, and the proximal edge of the plantar forefoot distally.

through its superficial and deep terminal branches. The boundaries of this angiosome are the junction of the heel and medial instep proximally, the midline of the plantar foot laterally, an arc 2–3 cm above the medial glabrous junction medially, and the proximal edge of the plantar forefoot distally (Fig. 3.3). While this angiosome may encompass the tissue of the hallux, this area is usually primarily supplied by the lateral plantar angiosome.

The superficial branch of the medial plantar artery provides dorsal anastomoses with the dorsalis pedis artery and the first dorsal metatarsal artery through cutaneous branches, and also lateral anastomoses with the first plantar metatarsal artery through deeper branches. The deep branch of the medial plantar artery provides lateral anastomoses with the first plantar metatarsal artery and the distal lateral plantar artery about the neck of the first metatarsal.

Lateral plantar angiosome

Following bifurcation, the lateral plantar artery travels through the central plantar compartment to form the important deep plantar arch with its four plantar metatarsal arteries extending distally to the digits. The boundaries of this angiosome are the junction of the heel and lateral plantar midfoot proximally, the lateral glabrous junction laterally, the midline of the plantar foot medially and the entire forefoot distally (Fig. 3.4). Again, this angiosome usually provides vascular supply to the hallux, but this area may also be supplied by the medial plantar or dorsalis pedis angiosomes (Fig. 3.5).

In addition to the previously described anastomoses with the medial plantar angiosome, the lateral plantar artery forms a very significant series of anastomoses with the dorsalis pedis artery in the metatarsal interspaces. The most important of these is formed in the proximal first interspace, although similar connections are typically found in the other proximal and distal interspaces.

Anterior tibial artery angiosomes

The anterior tibial artery supplies the anterior aspect of the leg and the dorsalis pedis angiosome of the foot. In the leg, the area overlying the anterior compartment is supplied from the anterior tibial crest to the fibula. Several anastomotic connections are formed just proximal to the level of the ankle joint. As previously described, the anterior medial malleolar artery supplies the tissue overlying the medial malleolus and connects with the posterior tibial source artery. Also at this level, the lateral malleolar artery supplies the tissue overlying the distal extent of the fibula and anastomosis with the anterior perforating branch of the peroneal artery.

Dorsalis pedis angiosome

The dorsalis pedis artery represents the continuation of the anterior tibial artery distal to the level of the ankle joint. The dorsalis pedis angiosome encompasses the entire dorsal aspect of the foot through the variable medial tarsal, lateral tarsal, arcuate and dorsal metatarsal arteries (Fig. 3.6).

These arteries contribute to important anastomoses with the other terminal arterial branches of the foot. As described earlier, there are anastomoses along the medial border of the foot between the

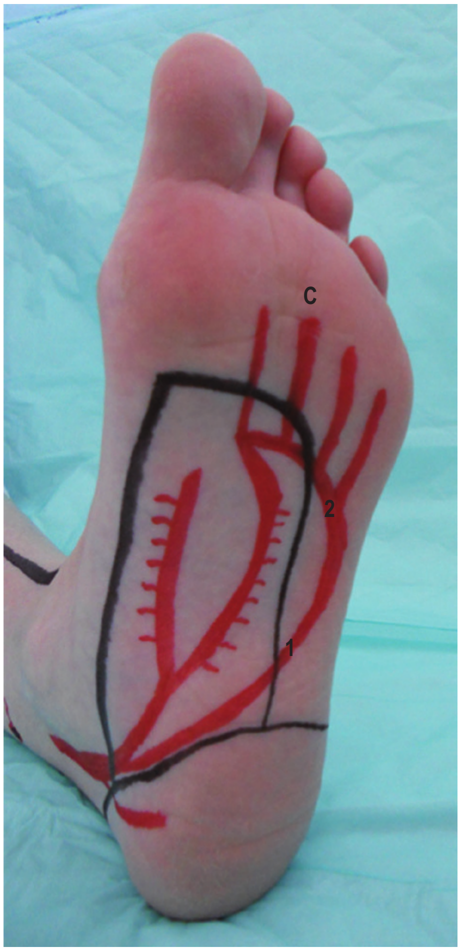

Figure 3.4 Lateral plantar angiosome. The primary source artery of the lateral plantar angiosome (C) is the posterior tibial artery by way of the lateral plantar artery (1). This artery forms the deep plantar arch (2) with its plantar metatarsal artery branches before anastomosing in the proximal first interspace. The boundaries of this angiosome are the junction of the heel and lateral plantar midfoot proximally, the lateral glabrous junction laterally, the midline of the plantar foot medially, and the entire forefoot distally.

superficial cutaneous branches of the medial plantar artery and the medial tarsal branches dorsally. The dorsalis pedis artery terminally bifurcates in the proximal first interspace as it forms an important anastomosis with the lateral plantar artery at the distal extent of the deep plantar arch. In the same way, there are often anastomoses between the dorsal and plantar metatarsal arteries in several locations (proximal and distal perforating arteries) in their respective interspaces. Anastomoses are also present between the proximal lateral tarsal arteries and the calcaneal and perforating branches of the peroneal artery.

Peroneal artery angiosomes

The peroneal artery supplies the tissue of the posterolateral aspect of the lower leg from the midline of the posterior calf to the fibula along the anterior edge of the lateral compartment. At the level of the lateral malleolus, the peroneal artery bifurcates into its terminal branches forming the final two angiosomes of the foot: the anterior perforating and lateral calcaneal arteries.

Figure 3.5 Hallux with varying angiosomal supply. The angiosomal supply to the hallux can be provided by the lateral plantar angiosome, medial plantar angiosome, dorsalis pedis angiosome, or combinations of these angiosomes.

(Reprinted from Attinger, C.E., Evans, K.K., Bulan, E., et al. 2006. Angiosomes of the foot and ankle and clinical implications for limb salvage: reconstruction, incisions, and revascularization. Plast Reconstr Surg Jun 117 (7 Suppl), 261S–293S.)

Lateral calcaneal angiosome

The lateral calcaneal artery travels along the peroneal tendons giving off several small calcaneal branches as it courses toward the base of the fifth metatarsal. Again, to fully appreciate the boundaries of this territory, the heel is divided into medial, posterior, lateral and plantar portions. The specific boundaries of this angiosome are from the posterior and lateral heel (an area covering the Achilles tendon insertion and the lateral heel to the base of the fifth metatarsal), across the entire plantar aspect of the heel to the medial glabrous junction. This territory extends as far distally as the junction of the heel and lateral plantar midfoot (Fig. 3.7).

There are anastomoses with the lateral tarsal arteries of the dorsalis pedis angiosome distally, and although it is not necessarily a true anastomosis, it should be noted that the majority of the heel is supplied by two overlapping source arteries: the posterior tibial and peroneal arteries.

Anterior perforating peroneal angiosome

The anterior perforating peroneal artery supplies a general area about the distal interosseous membrane and the anterolateral ankle. This is the specific region of the supramalleolar tissue flap. Anastomotic communication exists with the anterior lateral malleolar artery of the anterior tibial angiosome.

CUTANEOUS CIRCULATION OF THE SKIN AND SUPERFICIAL FASCIA

From this clinical anatomic perspective, these angiosomes represent the macrocirculation transporting blood to the level of the deep fascia in all areas of the foot and ankle. We can then view the cutaneous

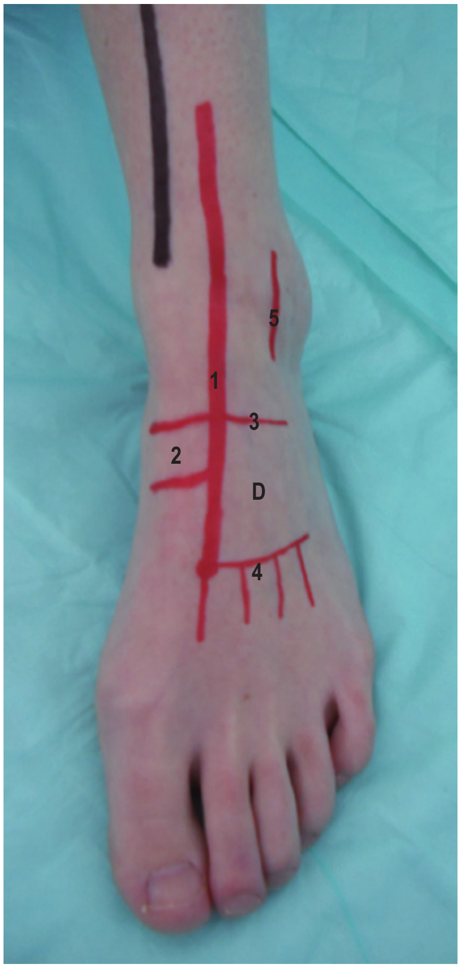

Figure 3.6 The dorsalis pedis angiosome. The anterior tibial artery serves as the primary source artery for the dorsalis pedis angiosome in addition to supplying the tissue of the anterior leg from the anterior crest of the tibia to the fibula. The dorsalis pedis angiosome (D) encompasses the entire dorsal aspect of the foot through the variable dorsalis pedis (1), medial tarsal (2), lateral tarsal (3), arcuate (4) and dorsal metatarsal arteries. The reader can also appreciate the anterior perforating branch of the peroneal artery (5) penetrating the distal interosseous membrane in this figure.

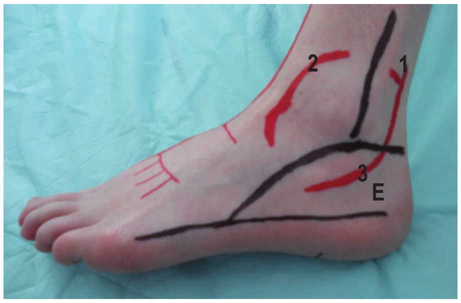

Figure 3.7 Lateral calcaneal angiosome. The peroneal artery (1) serves as the primary source artery for two angiosomes in the foot through its terminal bifurcation: the anterior perforating (2) and lateral calcaneal (3) branches. Prior to terminal bifurcation, the peroneal artery supplies the lateral lower leg from the posterior midline of the calf to the fibula. The boundaries of the lateral calcaneal angiosome (E) are the posterior and lateral heel (an area covering the Achilles tendon insertion and the lateral heel to the base of the fifth metatarsal), across the entire plantar aspect of the heel to the medial glabrous junction, and distally to the junction of the heel and lateral plantar midfoot.

circulation as the blood supply to the skin and subcutaneous tissue following perforation of the deep fascia. Taylor[1] describes the deep fascia as an 'enveloping body suit' covering the entire human frame, similar to the way that Bonica describes this layer as a 'second skin'[23,24] forming a developmental boundary between the superficial structures derived from the ectoderm (skin, superficial fascia) and the deeper structures derived from mesodermal tissue (muscles, tendons, joints, bones). Cutaneous arteries must penetrate through this layer in order to supply the skin and superficial fascia. This can occur either directly from the underlying source arteries, or indirectly from source artery branches supplying deeper tissues such as muscle. So conceptually, the cutaneous circulation to the skin and superficial fascia is from cutaneous perforators that arise from the deeper angiosomal macrocirculatory source arteries.

Cutaneous perforators pierce the deep fascia at fixed intervals depending on the specific anatomy of the location. This tends to occur at sites where the skin is fixed to the deep fascia such as skin crease lines, over intermuscular septae, near retinacular components, close to muscular insertions, and along the course of cutaneous nerves. Once the cutaneous arteries enter the superficial fascia, they organize into distinct layers forming a 'body carpet',[1] or plexuses on the undersurfaces of the subcutaneous fat and dermis. Each cutaneous perforator can then be thought of as supplying a three-dimensional unit of skin and superficial fascia with distinct layers and interconnections to adjacent cutaneous perforators. The cutaneous circulation of the lower extremity can be appreciated as these continuous plexuses that form uninterrupted horizontal layers within the skin and superficial fascia from cutaneous perforator to cutaneous perforator (Fig. 3.8). Capillary loops then arise from the subdermal plexus and provide a transition to the diffusion physiology of the microcirculation.[25–28]

Mechanisms of anastomosis

Anastomosis within the angiosomal circulation occurs deep to the deep fascia between adjacent source arteries, just as anastomosis within the cutaneous circulation occurs superficial to the deep fascia between adjacent cutaneous perforators. Both processes are regulated by the mechanisms of arterial-to-arterial connections, and allow neighboring angiosomes to share a common blood supply if one source artery is disrupted. The cutaneous vessels are under additional control of the sympathetic nervous system. Connections are open or closed as needed for the function of temperature regulation.

Direct arterial-to-arterial connections serve simply as a shunt where blood can pass from one angiosome to another through communicating arteries. Indirectly, choke vessels are found at the junction of angiosomal boundaries, but are normally closed and do not allow communication. The delay phenomenon explains how choke vessels can serve as safety conduits in the setting of source artery disruption, and allow the source artery from another angiosome to provide blood flow beyond its immediate border.[16,21,22] When the source artery to an angiosome has been disrupted, the choke vessels at the angiosomal boundary respond to the stress by opening and allowing communication. In this way, a threatened angiosome can be supplied by an adjacent source artery.

COMPROMISED VASCULAR STATES

The source artery supplying a given angiosome can become compromised because of acute or chronic conditions. As a peninsular end-organ, the lower extremity is particularly susceptible to the chronic

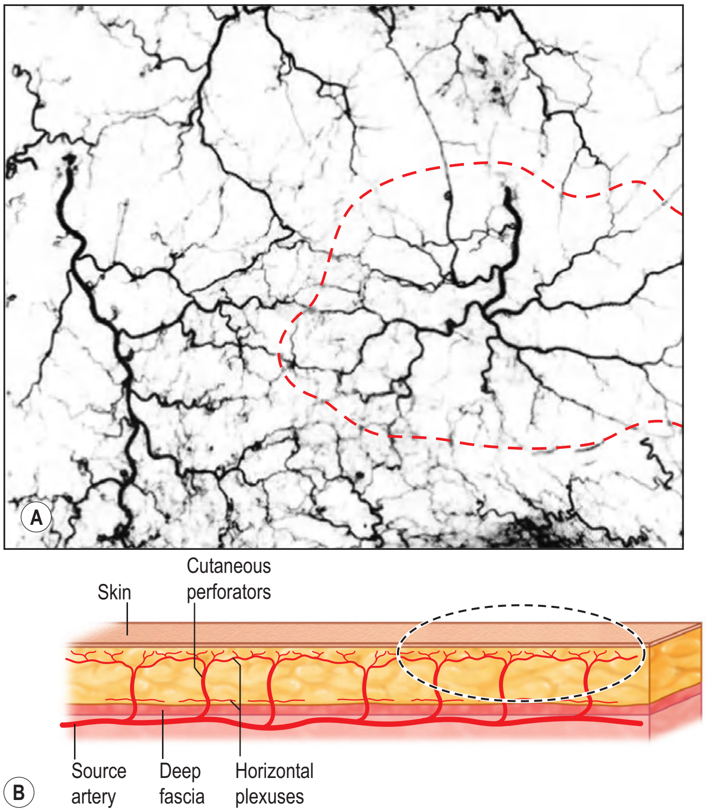

Figure 3.8 Cutaneous perforator continuous plexus. Figures A and B demonstrate the continuous nature of the cutaneous circulation as interconnected and uninterrupted horizontal layers within the skin and superficial fascia from cutaneous perforator to cutaneous perforator. *(Reprinted with permission from Taylor, G.I., Palmer, J.H. 1987. The vascular territories (angiosomes) of the body: experimental study and clinical applications. Br Plast Surg 40, 113–141.)*

manifestations of peripheral vascular disease. Impairment can occur within the specific source artery, but disease at a site more proximal along the vascular tree will also affect distal angiosomes. The superficial femoral artery is the most commonly affected in the lower extremity, and those with diabetes are particularly at risk for the type 1 pattern of disease with involvement of the superficial femoral artery and infrapopliteal trifurcation.[11,29–31] Direct and indirect affects on the angiosomal supply of the foot can be expected depending on the specific location and severity of the disease.

Physicians should also appreciate the potential for diffusion abnormalities with microvascular dysfunction in the setting of diabetes and other chronic conditions.[32–45] Surgeons are strongly encouraged to perform a thorough macro- and microvascular evaluation prior to the initiation of any surgical intervention. This evaluation is detailed in Chapter 1 of this edition, and the reader is further referred to other sources.[46–54]

Additionally, Attinger and colleagues[21,22] developed a physical examination technique of angiosome patency utilizing a handheld Doppler device and finger applied occlusion. This method not only provides the surgeon with information regarding angiosome source artery flow, but also the direction of that flow. For example, the source artery for the dorsalis pedis angiosome on the dorsum of the foot is the dorsalis pedis artery, anatomically a continuation of the anterior tibial artery distal to the ankle. Flow through the dorsalis pedis artery may arise directly antegrade from the anterior tibial artery, but it may also arise indirectly antegrade from the peroneal artery through the anterior perforating branch or lateral calcaneal artery, or from the posterior tibial artery through the lateral plantar artery, depending on the specific anastomosing patterns of the arterial-to-arterial connections. This system of evaluation presents the surgeon with a specific and detailed map of the vascular anatomy of a given surgical site, whether it is the ankle, heel, plantar aspect of the foot or dorsum of the foot. A review of the angiosome source arteries with their potential arterial–arterial connections is provided in Figure 3.9.

INCISION PLANNING

Exact incision placement represents a compromise between target tissue exposure, skin tension lines (with considerations for scar formation and joint contracture), adjacent neurological structures and vascular supply. From an entirely vascular perspective, an incision within a given angiosome is safe if a palpable pulse or triphasic Dopplerable signal is present from the source artery supplying that angiosome.[21,22] In situations of abnormal flow, extreme care must be taken to appreciate not only which angiosomes are deficient, but also where collateral anastomotic flow is coming from. An incision through an angiosome without a viable source artery should not disrupt the essential collateral flow from adjacent angiosomes.

When an incision is required at the junction of two angiosomes, the ideal location from a vascular perspective is along the exact border of both. Then each side of the incision has adequate flow from the respective source arteries. An example of this concept is illustrated by the extensile lateral approach used for open reduction of calcaneal fractures.[55] The proper location for the inferior arm of this incision is precisely at the lateral glabrous junction of the heel, which is directly at the boundary of two angiosomes. An incision, which has been displaced more superiorly into the lateral heel, puts the tissue between the lateral glabrous junction and the incision at risk for dehiscence and necrosis (Fig. 3.10). Attinger and colleagues[21,22] have made similar recommendations for incision placement at angiosome boundaries for other locations, and with multiple incisions in the foot and ankle.

VENOUS AND LYMPHATIC DRAINAGE

Although not usually the focus of surgical vascular anatomy, a brief description of the venous[56–60] and lymphatic[61–65] drainage of the foot and ankle will be reviewed here and should be considered in preoperative planning. The venous and lymphatic systems are organized in a similar manner to the arterial system, but naturally the flow moves from distal to proximal, and from superficial to deep. Comparable horizontal plexuses are formed within the skin and subcutaneous tissue, and the venous and lymphatic vessels generally travel with arterioles and arteries. In addition to his work with the arterial angiosomes, Taylor has also described the anatomy of the venosomes, or three-dimensional blocks of tissue served by a single source vein.[56] A simple rule of thumb is that wherever there is an artery, there are adjacent venous and lymphatic vessels.

The reverse of this statement is not true however, and often important veins and lymphatics travel without arteries within the superficial fascia. These drainage systems rely more heavily on the cutaneous circulation for proximal flow, and distinct superficial and deep venous and lymphatic systems are found. For example, the majority of the drainage from the dorsum of the foot and plantar heel occurs through

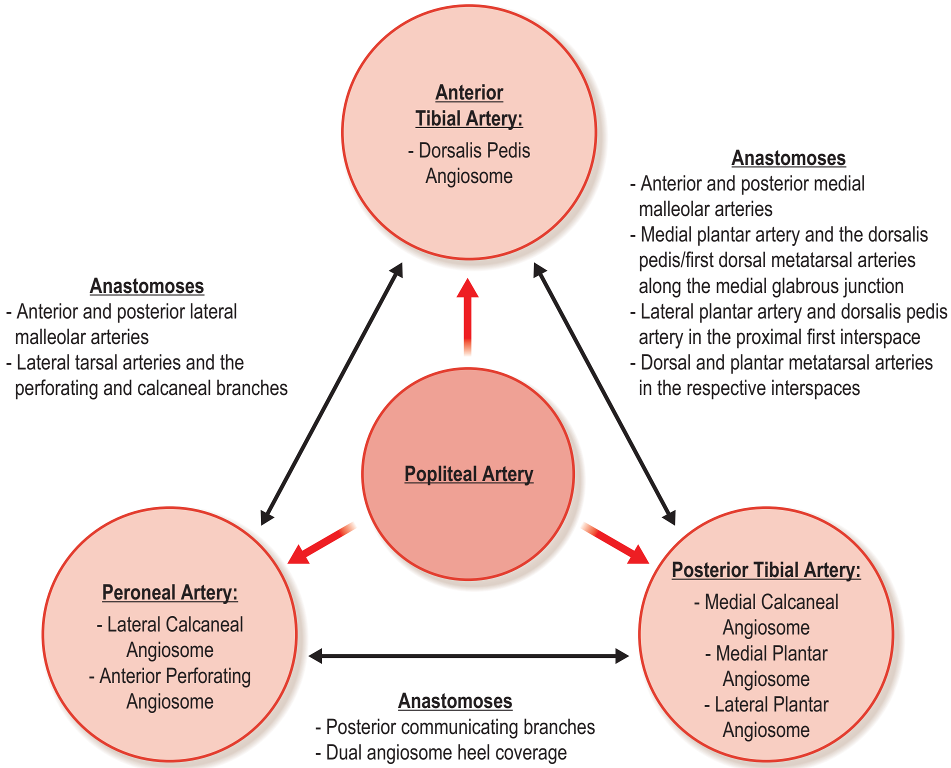

Figure 3.9 Source artery anastomoses chart. Anastomosis within the angiosomal circulation occurs deep to the deep fascia between adjacent source arteries, just as anastomosis within the cutaneous circulation occurs superficial to the deep fascia between adjacent cutaneous perforators. Both processes are regulated by the mechanisms of arterial-to-arterial connections, and allow neighboring angiosomes to share a common blood supply if one source artery is disrupted.

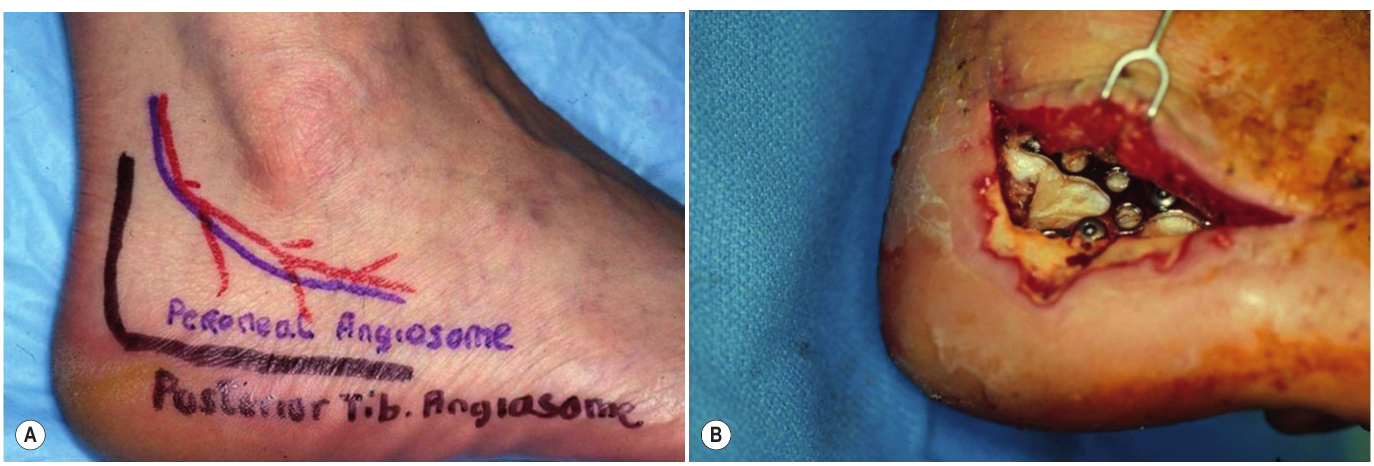

Figure 3.10 Incisions at the junction of two angiosomes. (A) When an incision is required at the junction of two angiosomes, the ideal location is along the exact border of both so that each side of the incision has adequate flow from the respective source arteries. An appropriate example of this concept is illustrated by the extensile lateral approach used for open reduction of calcaneal fractures. The proper location for the inferior arm of this incision is precisely at the lateral glabrous junction of the heel, which is directly at the boundary of two angiosomes. (B) An incision which has been displaced superiorly into the lateral heel puts the tissue between the lateral glabrous junction and the incision at risk for dehiscence and necrosis. *(Reprinted from Attinger, C.E., Evans, K.K., Bulan, E., et al. 2006 Jun. Angiosomes of the foot and ankle and clinical implications for limb salvage: reconstruction, incisions, and revascularization. Plast Reconstr Surg 117 (7 Suppl), 261S–293S.)*

the superficial system via greater and lesser saphenous veins.[14,57,58] If a surgical procedure is contained solely within the skin and superficial fascia, then the arterial supply to the region originates from deeper sources, but the expected venous drainage will be nearly entirely contained superficially. This concept becomes increasingly important when surgical procedures involve advanced reconstructions with various flaps (see Ch. 23).

CONCLUSION

The intended emphasis of this chapter is to provide the foot and ankle surgeon with a clinical appreciation for the specific vascular anatomy of the lower extremity and an appreciation of how angiosomal anatomy can directly influence the outcomes of surgical procedures.

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Chapter 4

Surgical principles

G. Dock Dockery

CHAPTER CONTENTS

INTRODUCTION

Surgical planning is the preoperative method of pre-visualizing a surgical intervention, in order to predefine the surgical steps and furthermore, any bone segment repositioning in the context of the final outcome. It is without question that surgeons must have detailed knowledge of the surgical principles, as well as surgical anatomy, of the areas in which they will be operating. This comprehension is also necessary for planning the local and regional anesthesia required to work efficiently and to carry out the procedures safely. Knowledge of the lower extremity cutaneous and surgical anatomy is of prime importance since this is the location in which the surgery is performed.

There are only a few important features that must be understood and handled with care when discussing most cutaneous surgery. In contrast, the lower extremity anatomical structures beneath the skin are much more complex and varied, and it is imperative that there is a detailed knowledge of these structures in order to prevent irreparable harm. It is a lack of understanding of the underlying structures that causes many serious complications involving the nerves, blood vessels and tendons. Therefore, it is crucial that new surgeons take every opportunity to improve their expertise of surgical anatomy by dissecting cadavers as well as reviewing textbooks and taking surgical techniques workshops provided by their surgical societies. Similarly, experienced surgeons must never become too cavalier in their surgical techniques that they forget the many complexly arranged elements involved in cutaneous reconstruction.

As soon as the surgeon has a good understanding of the general anatomy, as well as the cutaneous anatomy, it becomes much easier to plan and execute skin-related procedures. These skin procedures rely on the knowledge of the anatomical structures that lie directly below where the incisions will be performed. In the following section, the discussion will center on the surgical importance of skin properties such as contour lines, lines of maximum extensibility, relaxed skin tension lines, incision planning and, finally, incision-making techniques. Many of these surgical planning principles will be discussed in other chapters and greater details will be provided when necessary for individual procedures.

SKIN PROPERTIES

Contour lines

The contour lines are seen around prominent areas of the foot and ankle, including the toenails, the toes, the contours of the first and fifth metatarsals, the long extensor tendons, lateral peroneal tendons and the Achilles tendon to the heel. Other examples include the boundary of the medial and lateral ankle with the foot and leg. These lines divide the foot into functional units. During surgery on the foot and ankle, it is important that these contour lines be maintained as much as possible in order to reduce visible deformity.

Contour lines can also be effectively used to camouflage surgical scars, especially when combined with other techniques such as use of lines of maximum extensibility (LME) of skin and relaxed skin tension lines (RSTL). The functional units can be further divided into subunits. Thus, the toes can be divided into two sides, the dorsum and the plantar surfaces. Similarly, the forefoot is divided into the dorsum and plantar surfaces. The ankle is generally divided into the anterior and posterior, medial and lateral units and so on. In general, when using random pattern flaps and grafts, it is best to try to use skin from the same functional unit or subunit if possible. For example, if a defect is located on the plantar surface, it is best to use plantar skin for the repair.

Lines of minimal movement and relaxed skin tension lines

The lines of minimal movement (LMM) are similar to those described as RSTLs. The LMM indicate that very little motion occurs along that line and usually runs perpendicular to the LMEs. The RSTLs are related to the underlying musculature and osseous structures and are associated with creases that develop in the skin with normal flexion and extension, especially on the lateral and anterior region of the ankle. The skin reveals its greatest ability to stretch and relieve tension in a direction perpendicular to the RSTLs along the lines of maximum extensibility (Fig. 4.1). The RSTLs are not exactly identified on the foot and ankle, and many different guidelines have been developed as surgeons have searched for an ideal guide for elective skin incisions. Many surgeons prefer Langer's lines. These lines were described by Karl Langer in 1861,[1] an anatomy professor, from cadavers in rigor mortis. However, in 1951, Kraissl[2] published his preferred anatomic lines oriented perpendicular to the action of the underlying muscles. Later, the best model was based on a description by Borges and Alexander in 1962,[3] in which relaxed skin tension lines follow furrows formed when the skin is relaxed and are produced by taking the part through a range of motion (Fig. 4.2).

Skin tension is important in incisional and wound healing. An incision that is oriented such that tension across it is maximal, will result in a stretched, hypertrophic scar. This occurs when an incision is placed perpendicular to the RSTLs and the skin has minimal movement available along the lines of minimal movement. In contrast, an incision placed parallel to or within the RSTLs will result in less tension on the wound due to underlying anatomical structures. Incisions with little or no tension generally heal with a lesser degree of scarring. When it is not possible to stay parallel to the RSTLs, it is best to place the incision obliquely across the RSTLs. Unfortunately, in foot and ankle surgery, it is not always practical or advisable to do this, and in some cases the incision is best placed perpendicular to the RSTLs to obtain the best surgical exposure and least amount of harm to the underlying and surrounding tissues.

To best identify the RSTLs on the foot and ankle region, the area is simply taken through a normal passive or active range of motion and the crease lines that form in the skin may be observed (Fig. 4.3). In other parts of the foot, where motion is less, the RSTLs may be reproduced by pinching the skin between the thumb and forefinger and observing the crease lines that form. This same maneuver works in flexible joints without putting them through the range of motion process (Fig. 4.4).

Figure 4.1 The long axis of a semi-elliptical (fusiform) excision should follow the relaxed skin tension lines (RSTLs) to close the defect without tension. Excising the lesion following the lines of maximum extensibility (LME) might seriously jeopardize the closure and increase the scar size and thickness.

INCISION PLANNING

We have determined that it is best to place a surgical incision within the RSTLs and that, when this is not possible, the next best position for the incision is oblique to the RSTLs. In order to obtain the best surgical exposure, however, the incision may need to be placed at right angles to the RSTLs or direction of muscle/tendon pull over joints. Surgical incisions that cross over joints are more prone to scar formation and subsequent scar contracture. If the incision is curved as it crosses over the joint, there is a tendency to reduce the excessive scarring that might occur with a straight linear scar.

It is equally important to consider the structures underlying the skin when planning surgical incisions. The obvious structures include the muscles, tendons, nerves and blood vessels. Incisions placed parallel with the longitudinal neurovascular and muscle-tendon structures reduce the risk of injury to these entities and, therefore, reduce the overall postoperative complications. As was pointed out earlier, it may not be possible to comply with this principle all of the time due to accessibility of underlying structures. For example, on the anterior ankle, the tendons, blood vessels and lymphatic systems all run in a

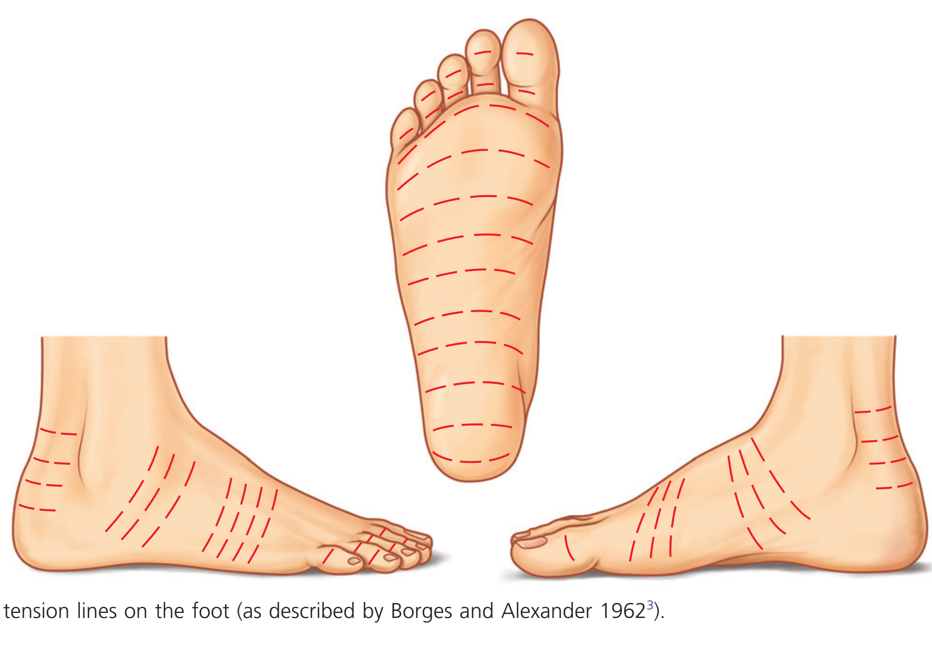

Figure 4.2 Relaxed skin tension lines on the foot (as described by Borges and Alexander 1962[3]).

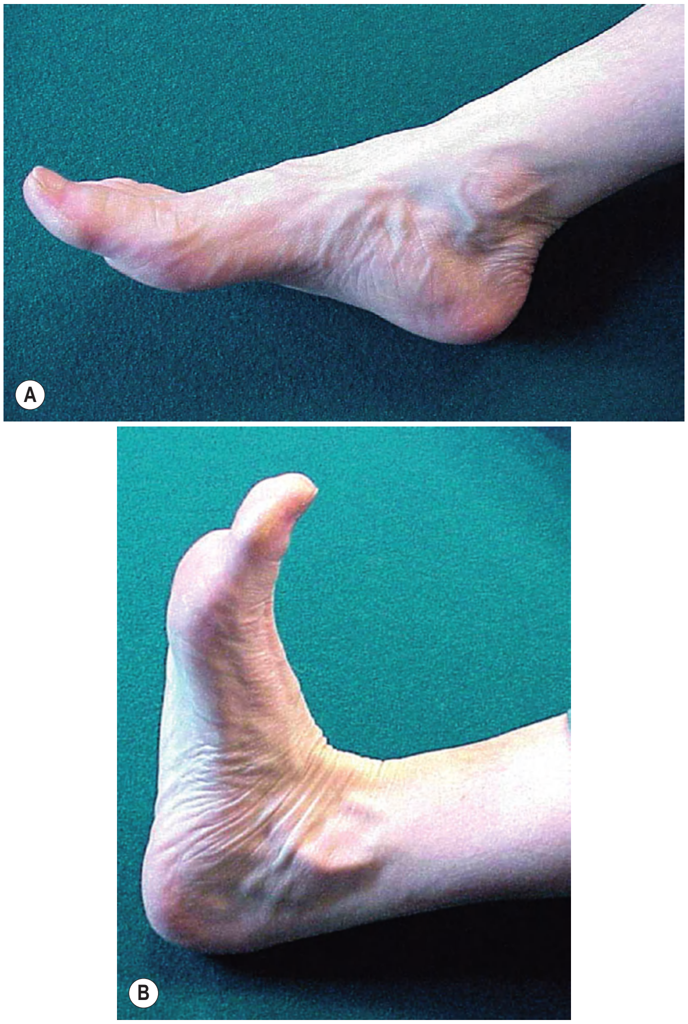

Figure 4.3 Reproduction of relaxed tension lines (RSTLs) with motion. (A) The RSTLs are not easily identified on the foot and ankle in a relaxed position. (B) The RSTLs around the foot and ankle can easily be visualized by dorsiflexion of the foot.

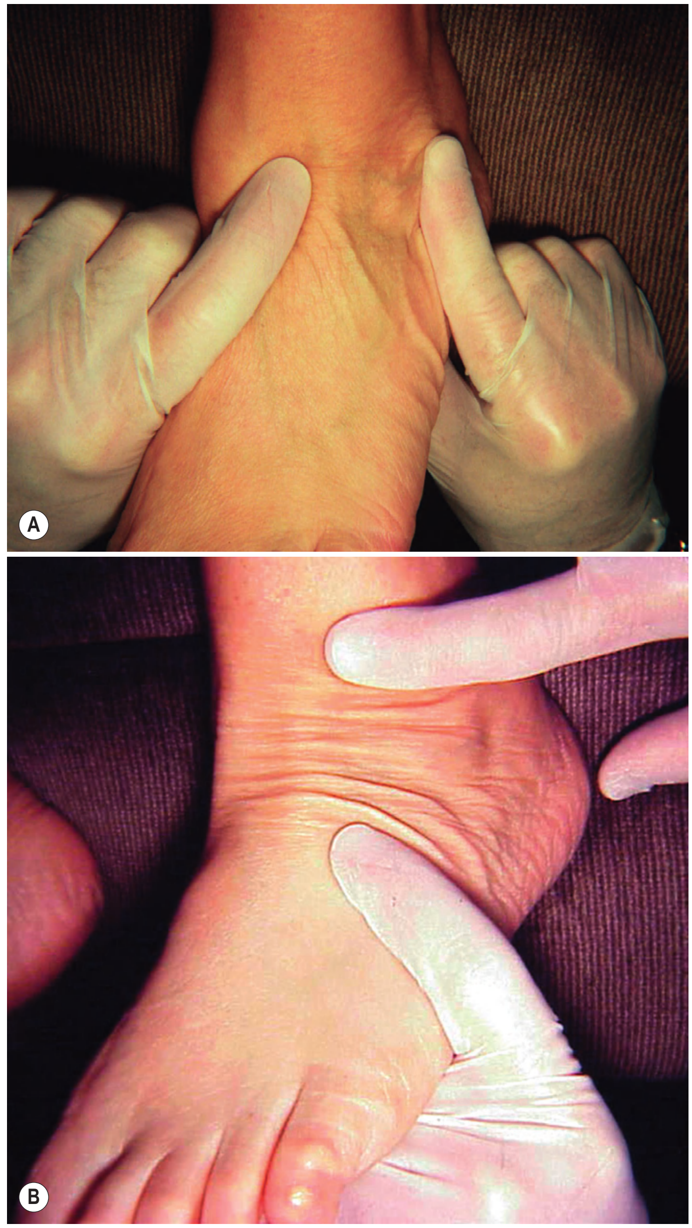

Figure 4.4 Reproduction of relaxed tension lines (RSTLs) with pinch test. (A) Pinching the skin perpendicular to the RSTL shows decreased skin movement. (B) Pinching the skin within the RSTL gives rise to a linear crease formation. By pinching the skin between the two angles, or oblique to the RSTL, an irregular or S-shaped pattern may be produced.

vertical linear pattern, but the RSTLs run transversely across the middle of the joint. The surgeon then must decide which of the principles of skin incision are to be violated. In all cases, the best choice is that which achieves adequate visualization and surgical access to the tissues rather than final scar formation.

Incision planning on the foot and ankle and lower leg require preoperative considerations of skin characteristics, underlying anatomical structures and the ultimate goal of wide exposure. However, incisional planning for the plantar foot must also take into account other factors, including pressure points, weight-bearing areas, and the increased thickness of the plantar foot skin. There is an increased risk of scar formation on the plantar foot unless several issues are addressed during the planning stage. The first consideration is the placement of the incision away from prominences and direct weight-bearing. This alone will reduce the potential for increased scarring and scar tenderness. Another consideration is the increased time needed to heal incisions placed on the plantar foot. It has been shown that the plantar foot scars can be minimized by careful planning of the incision placement and protection from motion and weight-bearing for a minimum of 3 weeks. Careful attention to these details will allow for soft and non-tender scar formation, even with complex rotational flaps and advancement flap procedures.

INCISION MAKING

The first few decisions in making the incision are on its placement, orientation and length. If the incision location is improperly chosen, then the exposure to the surgical condition may be limited. Similarly, if the orientation of the incision around bone or structural prominences is incorrect, the resultant scar may be problematic. Finally, if the incision is too short then the surgeon may require more extensive

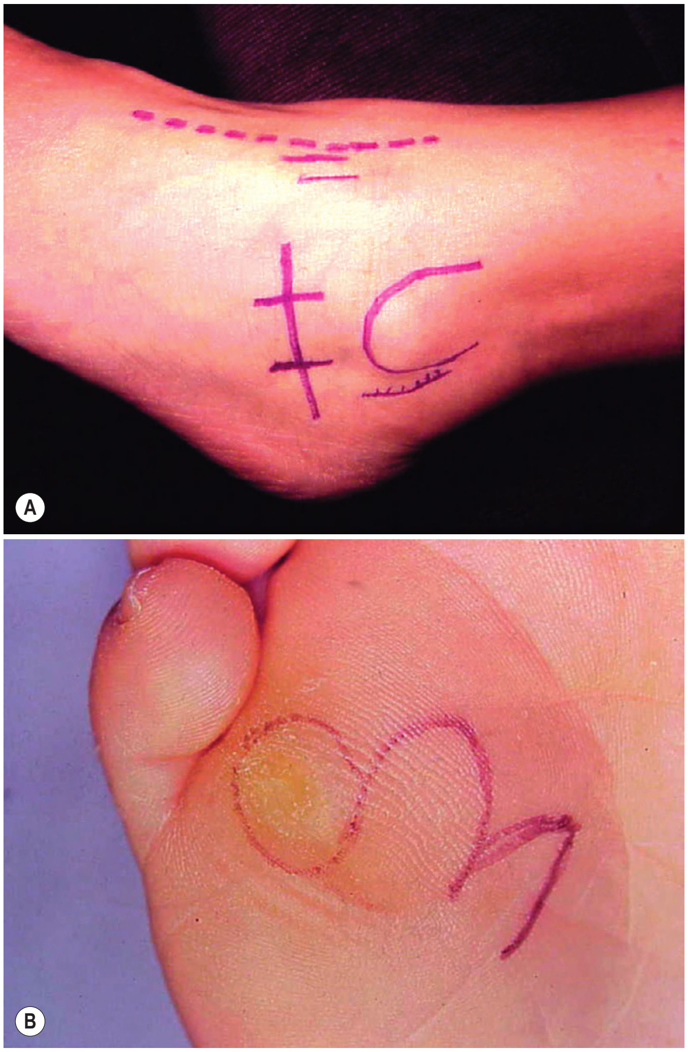

Figure 4.5 Incision making. (A) It is advisable to draw the planned incision with a skin-marking pen. Cross-hatching allows the incision edges to be realigned properly after completion of the surgery. Nerves and other anatomical structures are outlined for clarity. (B) Complex flaps or other incisions may be drawn out for accuracy of placement.

retraction for proper visualization, which may result in skin tears or increased damage to the skin edge from the retraction instruments.

In almost all cases, it is advisable to draw the projected incision line with a skin-marking pen. This allows for a much better visual picture of what the actual incision will look like and will guide the surgeon to a more accurate placement of the incision. Additionally, cross-hatching the marked incision line provides a nice guide to realign the skin edges at final closure of the incision (Fig. 4.5). Even skilled surgeons will routinely draw the skin incision placement prior to performing the procedure, especially when planning flaps or complex incisions.

The choice of surgical scalpel blade is based upon the location of the incision and the type of planned procedure. A No. 10 scalpel blade is frequently used for linear incisions on relatively flat surfaces or in larger skin areas. The No. 15 scalpel blade, because it is shorter and has a smaller radial arc, is more commonly utilized in curvilinear and circular incisions and in areas where greater control of the blade is warranted. The No. 11 scalpel blade may be used for small or intricate incisions and many surgeons prefer the even smaller mini-Beaver

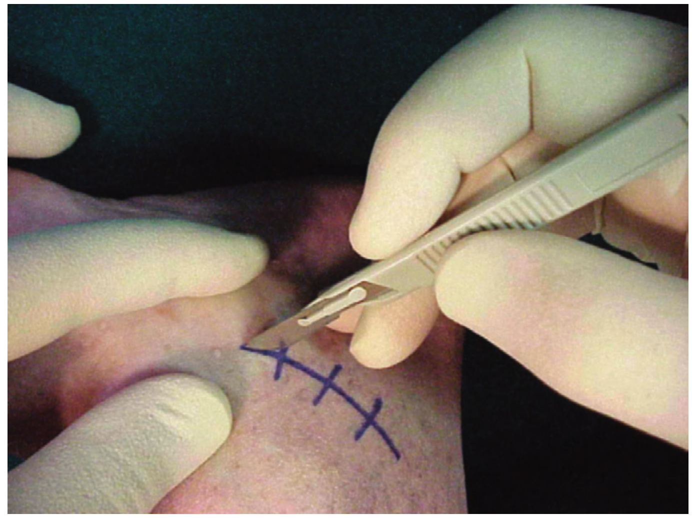

Figure 4.6 Skin tension for incision placement. It is helpful to apply tension to the skin on either side of the planned incision to help separate the tissue layers and maintain control of the incision depth.

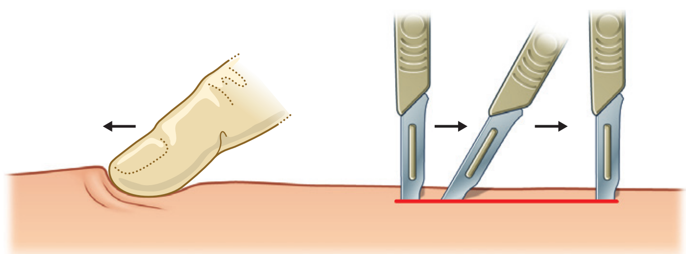

Figure 4.7 Incision technique. Start the incision with the tip of the scalpel and carry the incision to the end using the cutting belly of the blade and completing the incision with the tip of the scalpel.

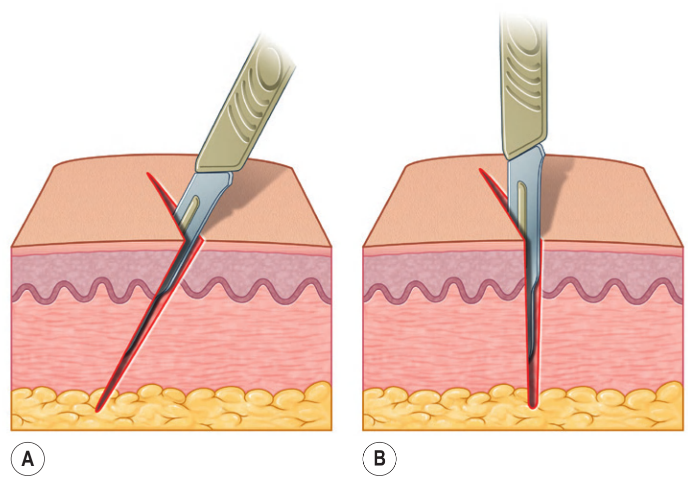

Figure 4.8 Incision technique. (A) Incorrect. A biased or skived incision may lead to poor healing and increased scar formation. (B) Correct. The incision is vertical and has greater potential for normal healing.

blades for toes or detailed excisions. Once the blade is selected, it is useful to apply tension on either side of the incision line to separate the tissues and to allow control of the incision depth (Fig. 4.6).

The initial incision should be made perpendicular to the skin surface and with one full-length swipe of the scalpel blade. This single-pass incision is best accomplished by starting the incision with the tip of the scalpel blade held in a vertical position perpendicular to the skin and then rolling onto the belly of the blade for the main portion of the incision and then completion of the incision with the tip of the blade again (Fig. 4.7). Multiple passes of the scalpel blade during the initial incision or cutting on a bias should be avoided at all times.

As the incision is being performed, care must be taken to assure that the surgical blade maintains its position and does not slip or be allowed to skive the skin and deep-tissue layers (Fig. 4.8). Slippage frequently occurs when: the skin is thick, the adjacent skin tension is lost or when a dull scalpel blade is being used. The biased transdermal incision is often made when: the surgeon is in an awkward position during the procedure, the incision is performed around prominent locations or around a significant curvature or when the operator is inexperienced. Both the slippage laceration and the biased skived incision can lead to wider scars, improper apposition of skin edges on closure or possible wound-healing problems.

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Chapter 5

Basic instruments and tissue handling

G. Dock Dockery

CHAPTER CONTENTS

As we get into the use of specific instruments for cutaneous procedures, we will discuss their individual applications and techniques available. Overall, it is important to be attentive to the application of sterile drapes and the use of towel clamps to secure them. It is more than just frustrating when the surgical assistant or nurse accidentally damages the patient's skin with the towel clamps. On the same subject, tourniquets need to be properly placed, padded and monitored to prevent additional skin damage. Whenever possible, it is best to avoid tourniquet use.

As will be pointed out subsequently, the use of new, sharp, knife blades using the proper technique will make a clean and even incision. The use of skin retractors is recommended in place of handling the tissues with skin forceps or pick-ups. Manual hand-held retractors are suggested rather than self-retaining retractors and sharp retractors are preferred over the blunt retractors in most cases. Finally, gentle tissue handling is essential during the process of incision closure.

TISSUE HANDLING

The general principle of tissue handling is very simple: *be gentle at all times*. This involves the initial approach of injecting the skin and deeper layers, marking the skin incision, draping the surgical area, making the incision and the careful use of retractors and other surgical instruments used during the procedure. The use of gauze sponges should be limited, and lavage and suction are preferred for removal of blood and fluids in the surgical site. When gauze sponges are used, the mechanism should be one of dabbing the wound gently rather than wiping or rubbing.

Keeping the tissue layers moist during the procedure is very important, and the use of frequent cool sterile flush and suction is encouraged. When sterile flush is used, it should be gently applied since forceful sprays of solution may spread tissue layers unnecessarily and cause tissue emphysema. This forceful flushing technique is reserved for wound irrigation in the presence of debris, foreign body particles or infection.

THE OPERATING ROOM

The operating room must obviously be large enough for the patient, surgeon, assistant and all necessary surgical and emergency supplies needed for the procedure. The room must be well ventilated and adequately illuminated, and it should have a variety of mobile lighting units that may be readily adjusted by the surgeon or assistant during the surgery, while maintaining sterility.

The operating table for the patient may be either an adjustable surgical chair or electronic flat operating table. Either unit should be easily adjusted in height by the surgeon, for either sitting or standing, and it should have an adjustable head support and be able to be repositioned with the head or foot elevated. The entire surgical table should be easily placed into the Trendelenburg's position with the patient's head down in case of an emergency. It is also advisable to have either attached armrests or detachable side extensions to support the patient's arm to receive intravenous solutions or medications.

SURGICAL INSTRUMENTS

Surgical instrumentation for plastic and soft tissue reconstruction is highly specialized, even although there may be several different instruments with the same function. The majority of skin procedures may be performed with just a few key instruments, although most surgeons prefer to use a wide variety of small plastic surgery instruments during a complex procedure. Eventually, each surgeon develops a fondness for particular instruments for specific procedures. It is best for cutaneous surgeons to become familiar with a variety of plastic surgery instruments, as well as their functions, in order to broaden the scope of tools available.

Instrument stand

The most common instrument stand used for basic plastic surgery procedures is a stainless steel dressing tray, frequently referred to as a Mayo stand (Fig. 5.1). This mobile support stand has an upper tray for supporting the instruments and a wide base for stability. When the instrument tray is wheeled into the surgery room, it can be positioned over the patient or the surgical site, without resting on the patient. This transportable adjustable tray makes access of the surgical instruments more efficient for the assistant as well as the surgeon. There are two basic formats of providing a sterile field for the sterile instruments. The most common is simply to drape the instrument tray with sterile Mayo stand covers and the other is to use autoclavable reusable instrument pads that have small grooves for holding the instruments in place.

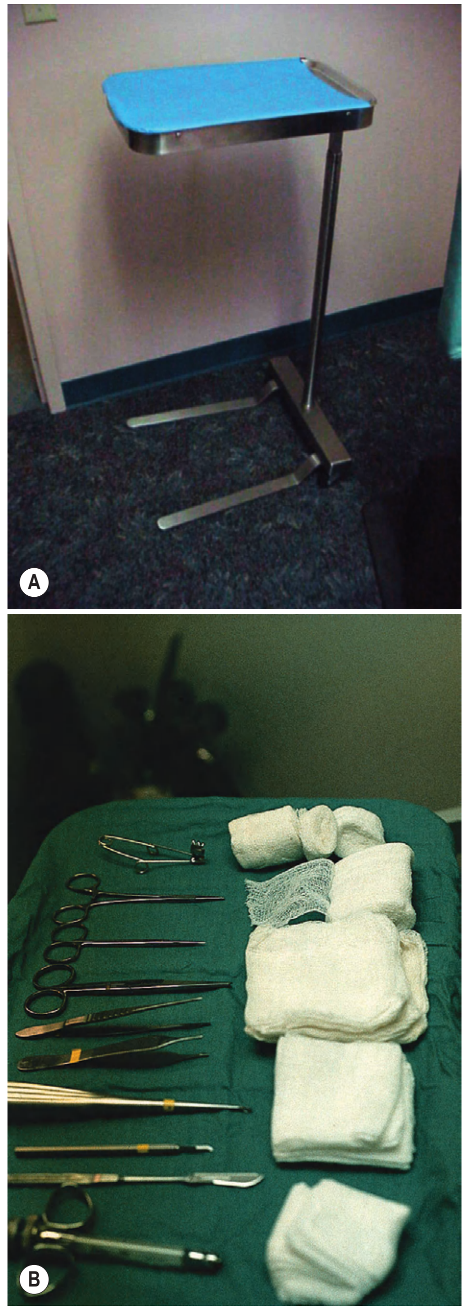

Figure 5.1 Mayo stand. (A) Typical Mayo instrument stand that may be placed close to the surgery site. (B) With sterile drape and surgical instruments.

Scalpel handles and blades

Generally, the term scalpel refers to both the handle and the cutting blade. The one-piece reusable scalpel is not very popular today and has been replaced with other styles of handheld scalpels with one-use disposable blades. The most commonly used scalpel handle is the Bard–Parker. The standard handles are the No. 3, No. 4 and No. 7 (Fig. 5.2). Of these handles, the No. 3 is most frequently used in foot and ankle surgery and it can be ordered with or without an imprinted ruler on one side of the handle (Fig. 5.3). The author prefers the handle with the ruler because it is useful for measuring the size of lesions, incisions or for planning skin flaps. For the smaller mini-blades, the $\frac{3}{16}$ inch diameter, rod-shaped mini-handles use a simple draw-in collet locking mechanism which, when tightened with the fingers, grips the mini-blade securely. The surgeon has maximum control of this style scalpel with a comfortable, cross-knurled pencil-grip design (Fig. 5.4).

All of the scalpels described may be held in two basic positions for making an incision. In general, the scalpel is held between the thumb and index finger with the middle finger supporting the handle from below, also called the ‘pencil grip’ (Fig. 5.5). The second position is similar, but with the scalpel held with the first three fingers, allowing the handle to be positioned in a lower attitude (Fig. 5.6). The pencil grip position allows for firm control of the scalpel while making precise or intricate incisions. The lower position is useful when much longer incisions are needed.

Disposable scalpel blades, constructed of high-quality surgical stainless steel, are available in a variety of sizes and shapes (Fig. 5.7). The No. 15 blade is suitable for most plastic surgery procedures; however, there are many instances when other sizes of blades will be more useful. For example, for a large incision on the posterior leg, a No. 10 blade, with its larger and more rounded design, might be more suitable. Likewise, for a much smaller incision or skin flap on a toe,

Figure 5.2 Bard–Parker scalpel handles. From top to bottom, No. 7, No. 4 and No. 3 handles.

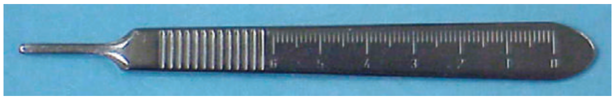

Figure 5.3 Close-up of No. 3 handle with engraved ruler on side.

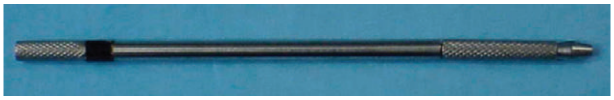

Figure 5.4 The Beaver mini-handle with cross-knurled pencil-grip design.

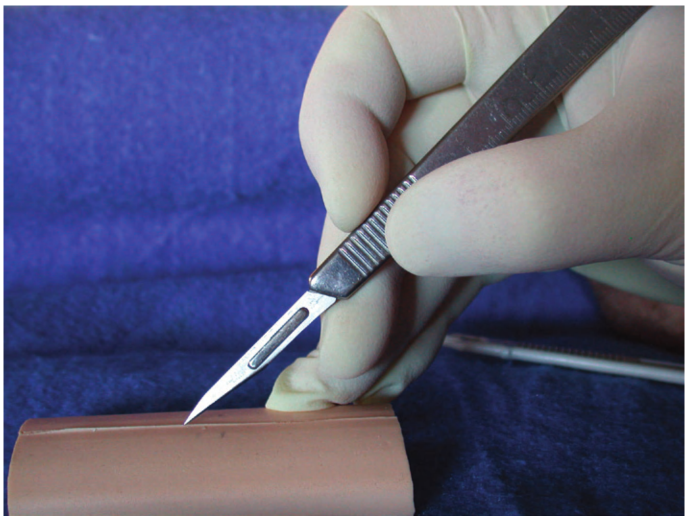

Figure 5.5 The standard position to hold the scalpel handle for best control while making precision cuts.

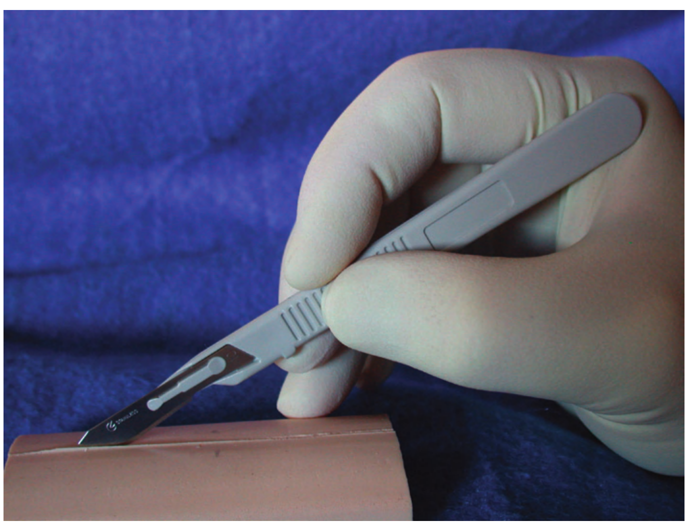

Figure 5.6 The alternate position to hold the scalpel handle for making longer incisions.

Figure 5.7 Surgical blades: No. 10, No. 15, No. 11 and Beaver mini-blade 64.

Figure 5.8 Disposable plastic scalpels: No. 10. Sizes 11 and 15 are also commonly available.

the No. 11 blade or Beaver mini-blade No. 64 or 67, might be preferable. Although not in common use today, several different styles of sterile disposable plastic scalpel holders with non-removable blades of standard sizes are available (Fig. 5.8).

As pointed out in earlier chapters, the surgical blade is designed to cut skin and soft tissues. The most effective method of making the incision is to begin with the tip of the blade, for accuracy, and then to use the sharpest portion of the belly of the blade for the incision, with completion of the cut utilizing the tip once again (Fig. 5.9).

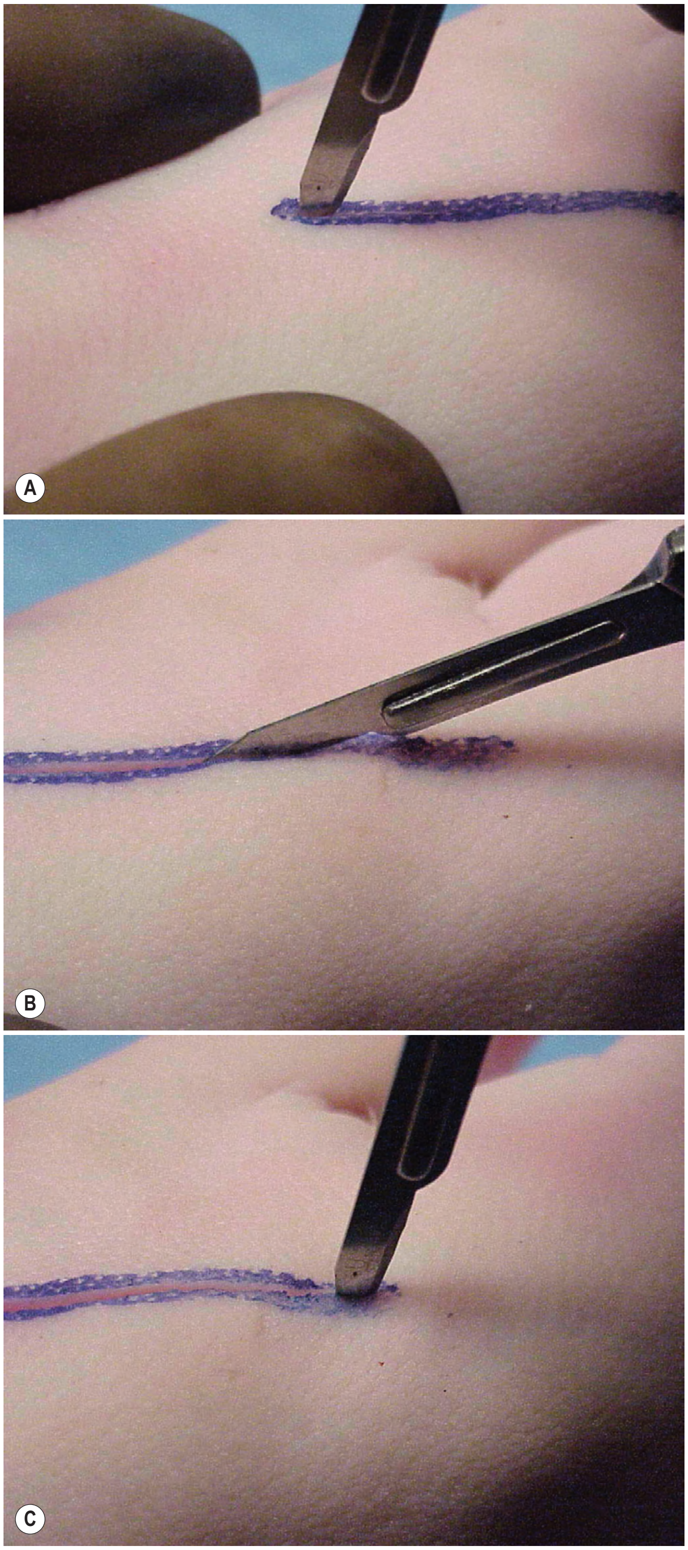

Figure 5.9 Photograph showing precise incision technique from tip to belly to tip of blade.

Tissue-handling forceps

These pick-ups or tissue forceps are designed to grasp or pick up tissue during the surgery. They are made in several different styles of tips and in different lengths (Fig. 5.10). Tissue forceps are generally held

Figure 5.10 Assorted tissue forceps. From top to bottom: long 1–2 Adson; Brown-Adson; short 1–2 Adson; fine serrated Hudson; fine smooth splinter forceps.

between the thumb and index finger (two-finger technique) or the thumb, index finger and the middle finger (three-finger technique) for finer tissue manipulation and control (Fig. 5.11). The pick-ups are available with or without teeth. The forceps with teeth are preferable for picking up tissue rather than by using the atraumatic style of forceps. It is a misconception that the pick-ups without teeth are truly atraumatic. It requires light pressure between the tips of toothed forceps to hold tissue securely, but it takes considerably more pressure between the tips of smooth or non-toothed pick-ups to hold the same tissue at the same tension. Therefore, there is more potential damage to the tissues being held by the forceps with no teeth. The most commonly used toothed forceps are the Brown–Adson tissue forceps, which have seven teeth on each side of the prongs (Fig. 5.12). The Adson tissue forceps have one tooth on one side and two teeth on the other side of the prongs of the forceps. They are frequently referred to as one-two or rat-tooth pick-ups due to this configuration of teeth. The fine Adson forceps are used during flap handling and for skin closure; however, care must be exercised with these forceps in most situations owing to the potential for tissue damage. It is common to see the Adson forceps used to handle suture material.

Other tissue forceps include the Adson, Hudson and iris forceps with serrated tips rather than teeth. All of these pick-ups must be handled gently to avoid tissue crush injury and are best used as retractors, rather than as grasping forceps. Another useful pick-up for cutaneous procedures is the fine-point splinter forceps. They also come with extra-fine and super-fine tips and may be used for bipolar electrosurgical coagulation of small vessels during the initial stages of the surgery.

Scissors

Scissors are very useful in plastic and reconstructive surgery and a wide variety of scissors are available (Fig. 5.13). Scissors are usually held with the thumb and middle finger in the finger loops and the index finger is placed under the rings or along the shaft of the scissor for stability (Fig. 5.14). Each type of scissors has been designed for a specific purpose and scissors designed for one purpose should not be used for another purpose. The four main functions of scissors are for cutting tissue, dissecting/undermining, suture removal and bandage removal.

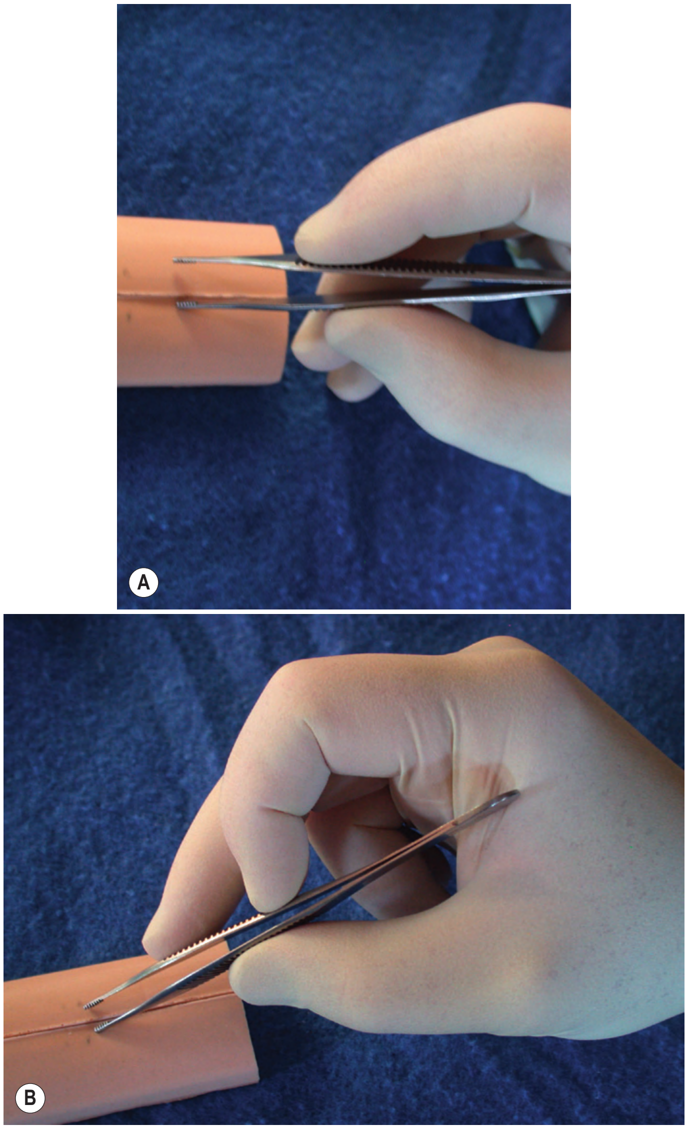

Figure 5.11 Pick-up techniques. (A) Holding tissue forceps in two fingers. (B) Holding tissue forceps with three fingers for fine control of the tips.

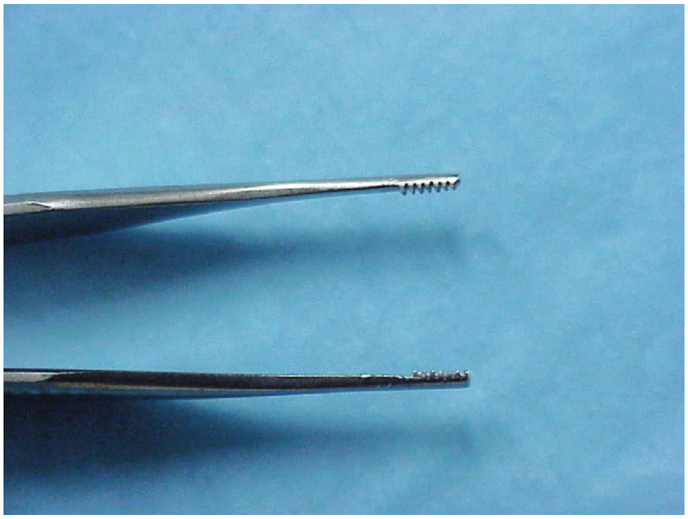

Figure 5.12 Close-up of the Brown–Adson 7×7 tissue forceps.

Figure 5.13 Assorted scissors.

Skin and tissue-cutting scissors are usually very fragile and are designed to sever tissue cleanly, even at the tips. They may be curved or straight and have sharp or blunt tips (Fig. 5.15). Straight scissors allow more exact straight-line cutting, while curved scissors provide an advantage in curved cuts and for removing small tissue attachments. The very small iris and tenotomy scissors are best used for fine or intricate work. These delicate scissors should never be used to cut sutures or bandages, as this will greatly reduce the lifespan of these scissors.

Dissecting scissors are typically used for the undermining of subcutaneous layers and deep tissues, have longer shanks and are usually blunt, but they may be either curved or straight in design (Fig. 5.16). The fine Metzenbaum scissors are commonly used for dissection purposes and may be used to cut lighter capsule and small fibrous tissue connections. The sturdier Mayo scissors are used to cut ligaments, larger fibrous bands and thick capsular tissues. In the deep layers, and in subcutaneous dissection, the dissection scissors may be used by either direct visualization cutting or by placing the closed scissors into the tissue layer and spreading the blades apart. This allows a controlled blunt dissection to occur, which provides better visualization for further tissue cutting within the new layer.

Stitch or suture scissors may be straight or curved, but are usually blunt to prevent damage to adjacent tissues during the suture cutting process (Fig. 5.17). Spenser stitch scissors have a small hook on one side to allow easy positioning of the scissors against the suture to be cut. In many cases, the standard 4½-inch operating scissors with one sharp and one blunt point are used as suture scissors (Fig. 5.18).

Bandage scissors, as a rule, are the least sophisticated of the scissors. The typical style is the Lister bandage scissors, with angulated blades and a large blunt end to allow slipping between the patient and the bandage (Fig. 5.19). The heavy-duty utility and bandage scissors is another popular model with serrated blades and needle destroyer (Fig. 5.20). It is best to use the bandage scissors on the outermost layers of wound bandaging or cast padding, and then carefully remove the deep dressing covers without cutting them. In some instances, however, the deeper bandage layers may be difficult to unwrap due to dried blood or serous drainage, and in this case, the bandage scissors may be useful in freeing the dressings. It is tempting to use any scissors that are available when bandages need to be removed, but it is wise to refrain from using non-bandage scissors for this heavy-duty job.

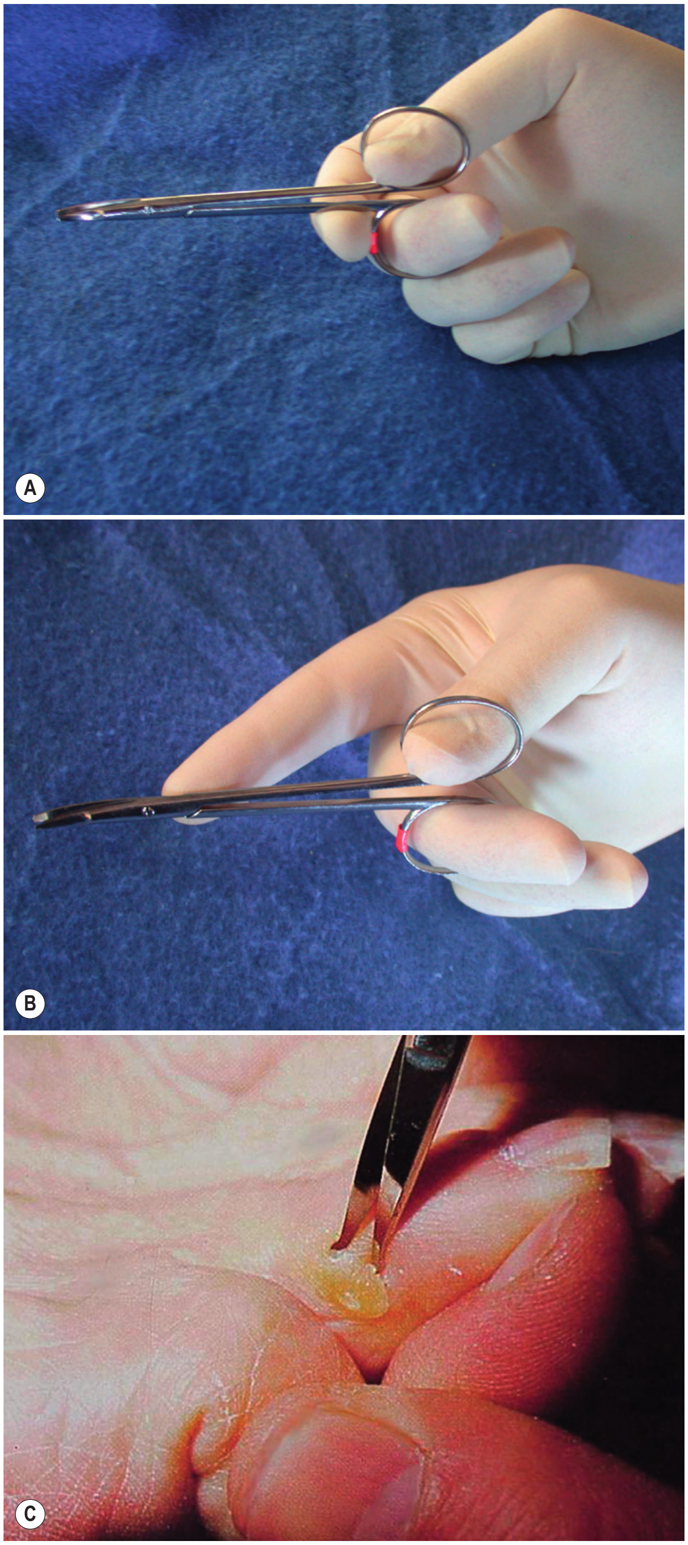

Figure 5.14 Correct holding position for cutting scissors. (A) Standard position with index finger under the rings. (B) With the index finger along the shaft for greater stability. (C) Using the tissue scissors to remove a skin lesion.

Figure 5.15 Skin and tissue scissors, sharp and blunt, curved and straight.

Figure 5.16 Dissection scissors: Mayo and Metzenbaum.

Tissue retractors

Tissue retractors are used to assist the surgeon in exposure of underlying structures, while protecting adjacent important structures. A variety of different styles of tissue retractors are available (Fig. 5.21). The two basic types of retractors are the hand-held and the self-retaining forms. The hand-held retractors allow an assistant to move tissue out of the way of the surgical instruments and protect the vital structures during the procedure. The advantage to the hand-held retractors is that the assistant can easily and quickly reposition them for added exposure and, at the same time, adjust the tension or force on the tissues as needed. The obvious disadvantage is that the surgeon needs the help of another person, the assistant, in order to have good retraction with these instruments. The advantage of the self-retaining retractors is that the surgeon can position this retractor without assistance. The disadvantages of the self-retaining retractors are that they may cause tissue damage by being placed in the incision with too much tension, or they may be left in place for an extended time. Therefore,

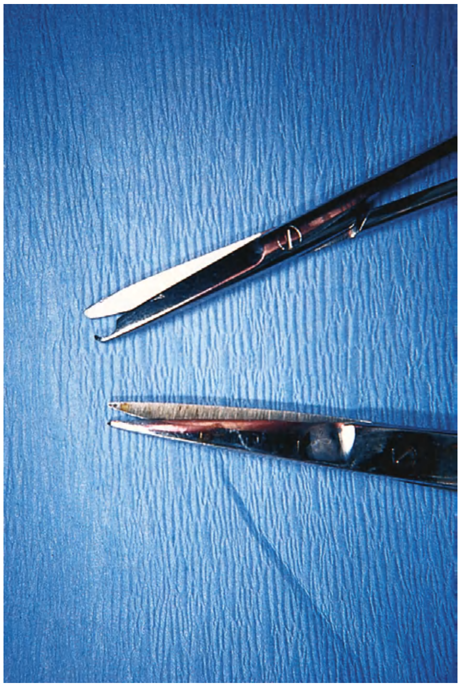

Figure 5.17 Suture scissors. Spencer scissors with a hook on one blade and straight suture scissors below.

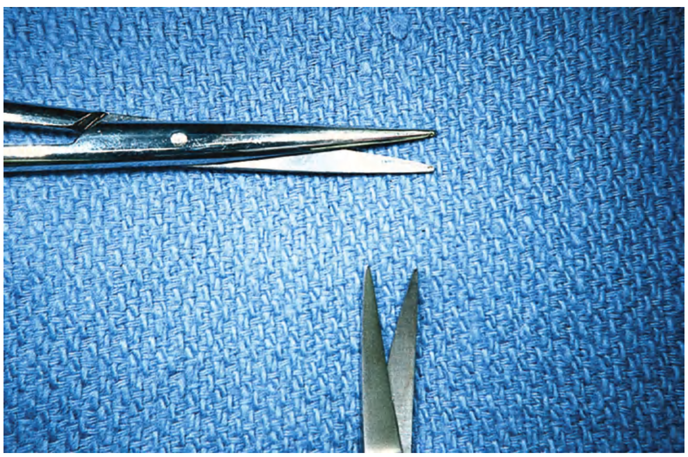

Figure 5.18 Standard 4½-inch operating scissors may also be used to cut sutures.

Figure 5.19 Lister bandage scissors.

Figure 5.20 Comparison of utility and Lister bandage scissors.

Figure 5.21 Several different styles of tissue retractors, both hand-held and self-retaining are available.

it is recommended that the self-retaining retractor be repositioned regularly to prevent the constant pressure of the retractor from being isolated to a small area. At the same time, the tension should be adjusted to the minimal amount that allows for adequate exposure.

Skin hooks and regular retractors are preferred in most plastic surgery procedures, since they allow for precise tissue manipulation during the procedure and, because of their design, do not crush tissue during retraction. They may have single, double or triple prongs with sharp or blunt tips. The double-pronged skin hooks provide better holding power, even though the single-pronged skin hooks are used more frequently. Sharp-tipped hooks are preferable to the blunt tips for better ability to perform skin eversion and for maintaining better visualization. Most skin hooks range from 4½ to 6 inches in length with an assortment of different sized hooked tips available. The delicate Tyrell skin hook has a 1.5 mm diameter, single hook on the tip (Fig. 5.22), while the slightly larger Freer has a 2 mm diameter, single or double hook and the Frazier skin hook is 2.5 mm in diameter. The

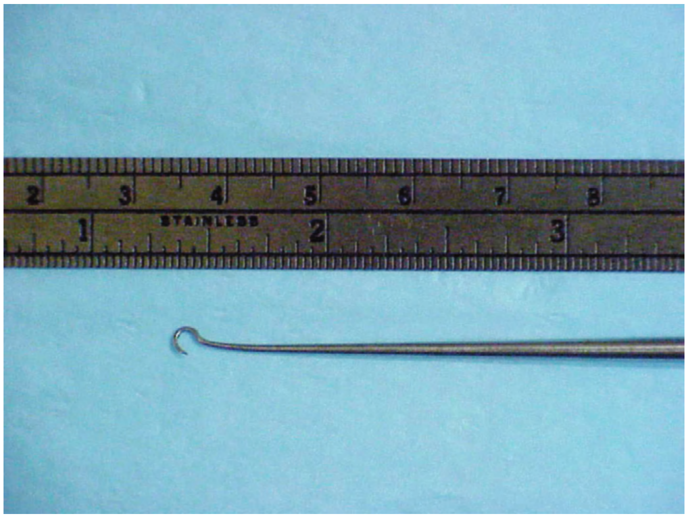

Figure 5.22 Fine delicate Tyrell skin hook, for delicate flaps.

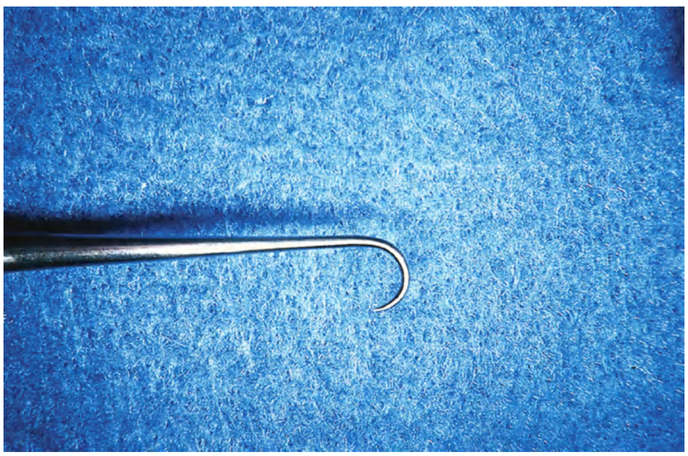

Figure 5.23 Close-up of Wiener skin hook tip, for most retraction purposes.

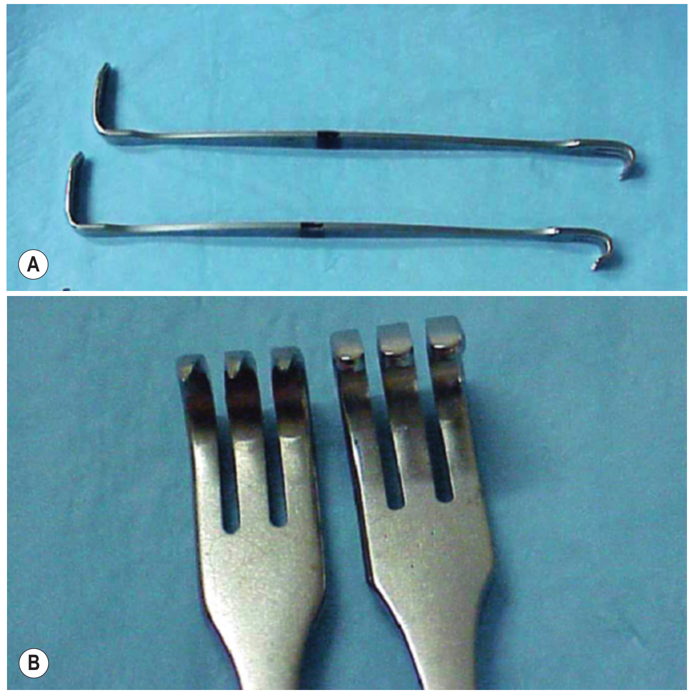

Figure 5.24 Senn tissue retractor. (A) Full view of two instruments. (B) Close-up of sharp and blunt tips.

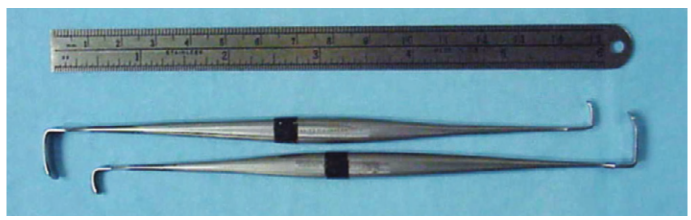

Figure 5.25 The 6-inch blunt Ragnell tissue retractors are commonly used in soft tissue surgery.

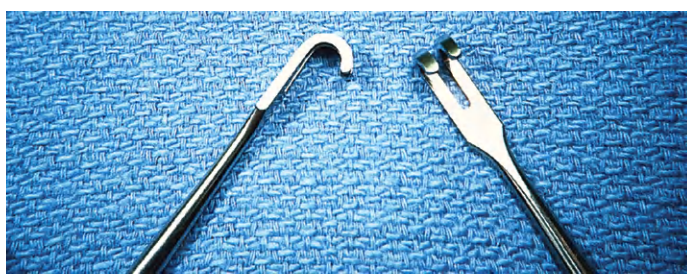

Figure 5.26 Rigid rake tissue retractor. They may have two or three prongs that are blunt or sharp.

standard Wiener skin hook has a 3.5 mm diameter, single hook on the tip (Fig. 5.23).

Regular tissue retractors range from 5 to $6\frac{1}{2}$ inches in length. The most common style is the double-ended Senn retractor, $6\frac{1}{2}$ inches in length, with three sharp or blunt curved prongs on one end and an angled blade on the other end (Fig. 5.24). The Ragnell retractor is also a double-ended retractor, 6 inches in length, with one 4 mm by 8 mm angled blade on one end and a 6 mm by 15 mm angled blade on the other end (Fig. 5.25). The rigid rake retractor, 6.5 inches in length, may have either two or three blunt or sharp prongs on one end only (Fig. 5.26).

The two most common self-retaining retractors used in plastic procedures are the 4-inch, cross-action three or four-pronged sharp or blunt self-retaining retractor (Fig. 5.27), the 4-inch, two by three and the three by four blunt or sharp pronged, Weitlaner self-retaining retractor (Fig. 5.28).

Artery forceps or mosquito hemostats

The most common hemostat used in plastic surgery is the Halsted 5-inch, straight or curved tip mosquito (Fig. 5.29). The straight-tipped forceps, with the regular or delicate teeth, is the most versatile hemostat, although the curved-tipped forceps are very useful for blunt undermining and for clamping small blood vessels during procedures. Other types of artery forceps include the $3\frac{1}{2}$-inch Hartman mosquito hemostat and the larger $5\frac{1}{2}$-inch curved or straight Kelly or Crile forceps (Fig. 5.30). The larger and heavier forceps are cumbersome and have little application in most plastic surgical procedures, except when a strong hold is needed, such as with large muscle or fascia transfers.

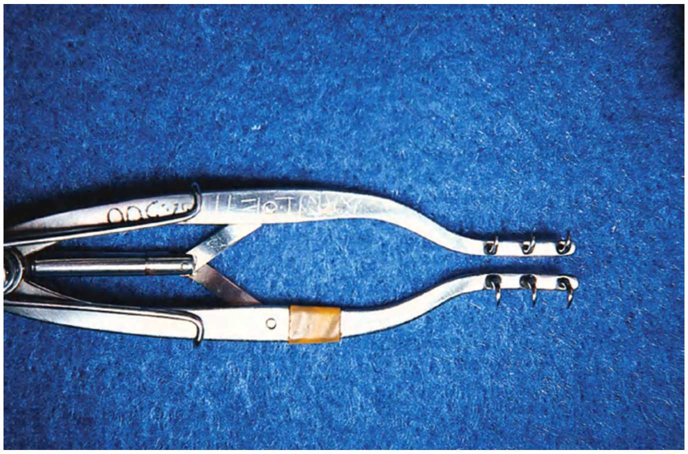

Figure 5.27 Small self-retaining three-pronged sharp retractor.

Figure 5.28 Weitlaner self-retaining retractor.

Figure 5.29 Curved and straight Halsted 5-inch mosquito hemostat forceps.

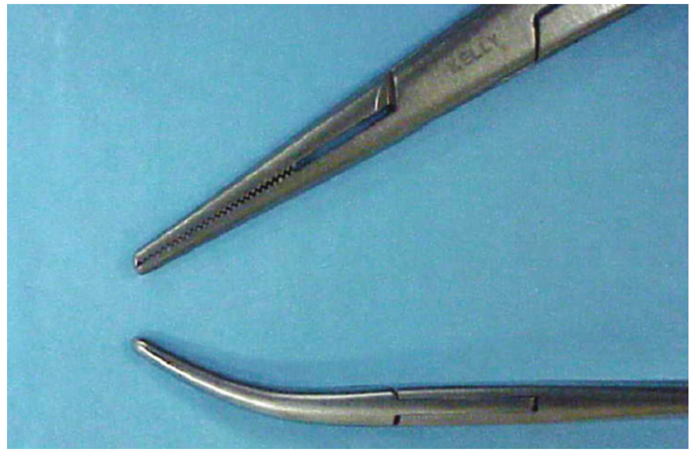

Figure 5.30 Curved and straight Kelly or Crile forceps.

Figure 5.31 Assorted needle drivers.

Needle holders/drivers

Needle holders, or needle drivers, come in a variety of styles and sizes (Fig. 5.31). The selection of needle holder from this large choice of instruments depends upon the nature of the procedure and the operator's preference. They should be comfortable as well as functional. Needle holders are available with smooth or cross-serrated jaws that are capable of holding a large assortment of different sized needles. In general, the smooth jaws are useful with small, delicate, needle sizes and the cross-serrated tips are designed to allow for a firm grip on the needle or suture. The cross-serrated tips, however, may cause damage to the suture material, such as the braided types and may damage the needle, especially at the tip.

The Olsen–Hegar needle holder has the advantage of having scissors directly behind the jaws, which saves time if an assistant is not present during the procedure. The disadvantage of the driver and scissor combination is simply that it is harder to master the combination of instruments. The most multipurpose driver is the 5-inch Mayo-Hegar needle holder (Fig. 5.32). It is supplied with the smooth, standard cross-serrated or the carbide inlay tips. The author prefers the newer tungsten-carbide inserts and feels that they provide a better grip on

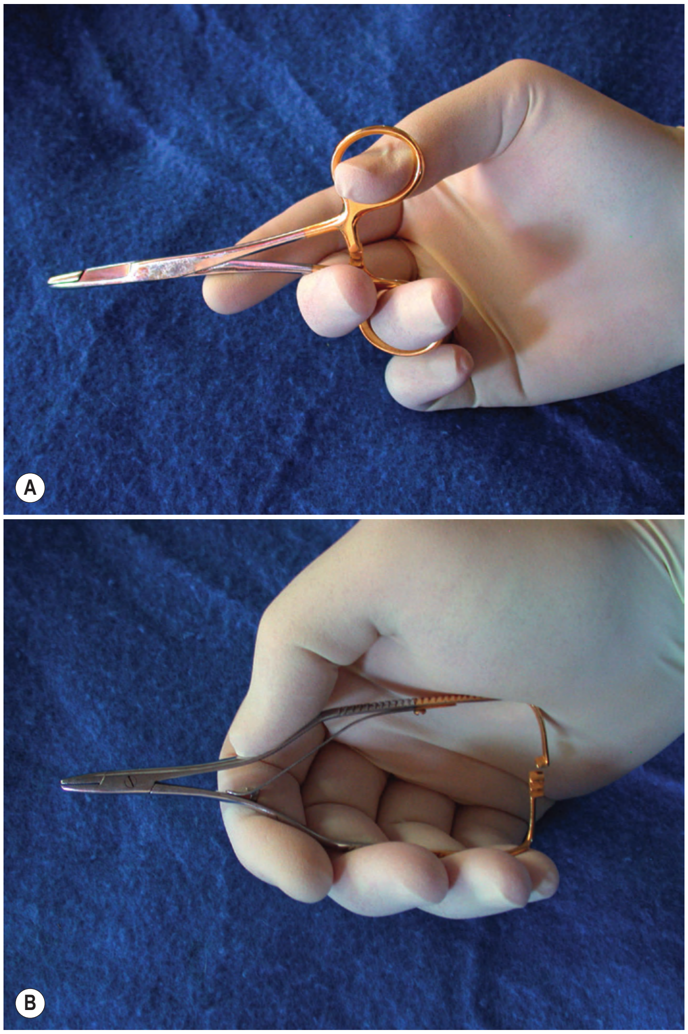

Figure 5.32 Needle holder showing proper hand position. (A) Finger and thumb control. (B) Hand control. Both types of needle holders can be held in the hand-control position.

small or medium-sized needles, and tend to grasps suture firmly without causing fraying or tearing. The hand-controlled needle holders may be faster to maneuver, but they take a little practice to use them comfortably. The longer-handled needle drivers are useful in placing deep sutures and the larger instruments with heavy jaws are more practical in holding larger needles for suturing fascia or tendons.

Punches

Punches used for biopsies of skin lesions are usually of the sterile packaged disposable type, which have one-time usage stainless barrels and plastic handles (Fig. 5.33). They are preferred over the reusable Keyes punch biopsy units since they provide the advantage of always being clean and sharp. Punches are available in a wide variety of diameter sizes, at 2.0, 3.0, 3.5, 4.0, 4.5, 5.0 and 6.0 mm. The most common are the 3.0 mm and the 4.0 mm diameter punch for lower extremity biopsies; however, using two 2.0 mm diameter punches is becoming much more popular than using one 4.0 mm punch of the same lesion (see Ch. 13).

Figure 5.33 Disposable punch biopsy units. (A) Individually packaged for convenience. (B) Close-up of 4 mm disposable punch unit.

Miscellaneous instruments

Although there are numerous other instruments that may be used during reconstructive and plastic surgery procedures, the ones discussed earlier are the most common and the most popular. Some specialized instruments have found a place in the cutaneous surgeon's toolbox. Tissue and periosteal elevators, such as the Freer and Sayre, may be used to undermine tissue, aid in dissection of tissue planes or in removing tissues firmly adhered to bone (Fig. 5.34). Single and double-ended bone rasps are also occasionally needed for removal of bone irregularities or spurs (Fig. 5.35). Bone-cutting forceps and Rongeur bone forceps are useful when large bone needs to be cut or removed (Fig. 5.36).

Small malleable retractors may be useful in some situations, such as retracting larger structures or passing beneath small tendons (Fig. 5.37). In addition, incision closure may be facilitated by using an automatic skin stapler (Fig. 5.38). This skin stapling process in many cases will be much faster than standard suture techniques and is frequently used in situations where strength of the closure material is an issue. For longer cases, the staples make the tedious final closure go much faster (Fig. 5.39). The staple removal system is also easy to use and the patients tend to report very little discomfort during the staple removal process.

It can be very advantageous to work with a specialized small surgical instrument company and get to know their representatives. They can often work with the surgeon to make a wide variety of instruments available that make precision skin surgery easier and often they can order special instruments that are not readily available with many

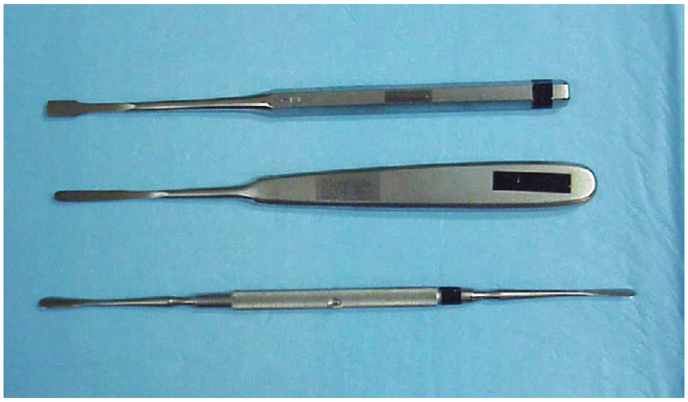

Figure 5.34 Periosteal elevators.

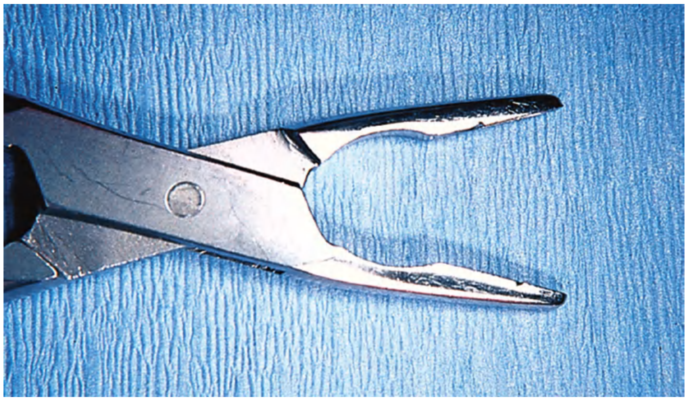

Figure 5.36 Rongeur bone forceps.

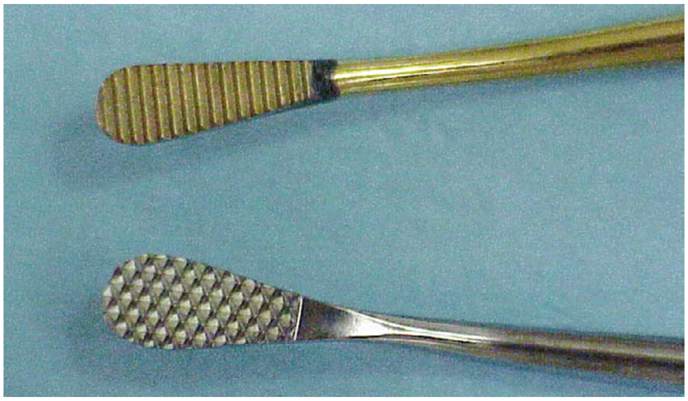

Figure 5.35 Bone rasps. Single-roll and cross-hatch styles.

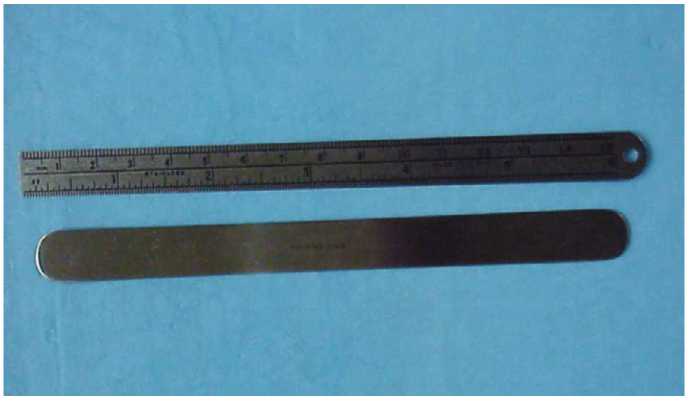

Figure 5.37 Small malleable retractor and ruler.

instrument companies, such as small self-retaining retractors and specialized scissors (Figs 5.40–5.43).

HAND SIGNALS IN SURGERY

Since much of soft tissue and plastic surgery of the lower extremity is performed under local anesthesia or with mild sedation, many of our patients are able to communicate during the surgical procedures. They also hear the conversation of the operating room personnel and physicians. Much of this normal operating room conversation may be misunderstood or create a great deal of unnecessary anxiety in some patients. A '4 by 4' may be interpreted as a piece of lumber, a 'mosquito' may be seen as an insect or the word 'rake' might bring visions of the garden to mind.

In order to decrease much of the uneasiness of this technical terminology and to put the patient more at ease, it is recommended that the surgeon and the surgical scrub assistant learn to communicate much of the normal jargon with non-verbal hand signals. There are standard recommendations for requesting surgical instruments and supplies using hand signals but the surgical team that works together frequently may make up their own signals for everything needed during the operation.

The most commonly requested instruments include: the scalpel or knife (Fig. 5.44); the tissue forceps (pick-ups) (Fig. 5.45); the scissors (Fig. 5.46); the mosquito (hemostat) forceps (Fig. 5.47); the needle holder/driver (Fig. 5.48); retractors, both sharp (Fig. 5.49) and blunt (Fig. 5.50) and a straight periosteal elevator (Fig. 5.51). Many other hand signals are used to indicate ligature suture ties, bone cutters, saline flush, gauze sponge, specific power equipment and to indicate continuing or to stop.

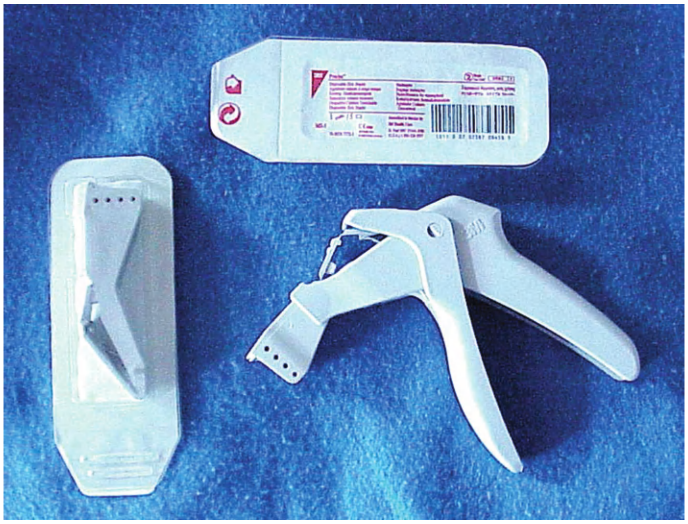

Figure 5.38 Skin stapling system (3M Corporation).

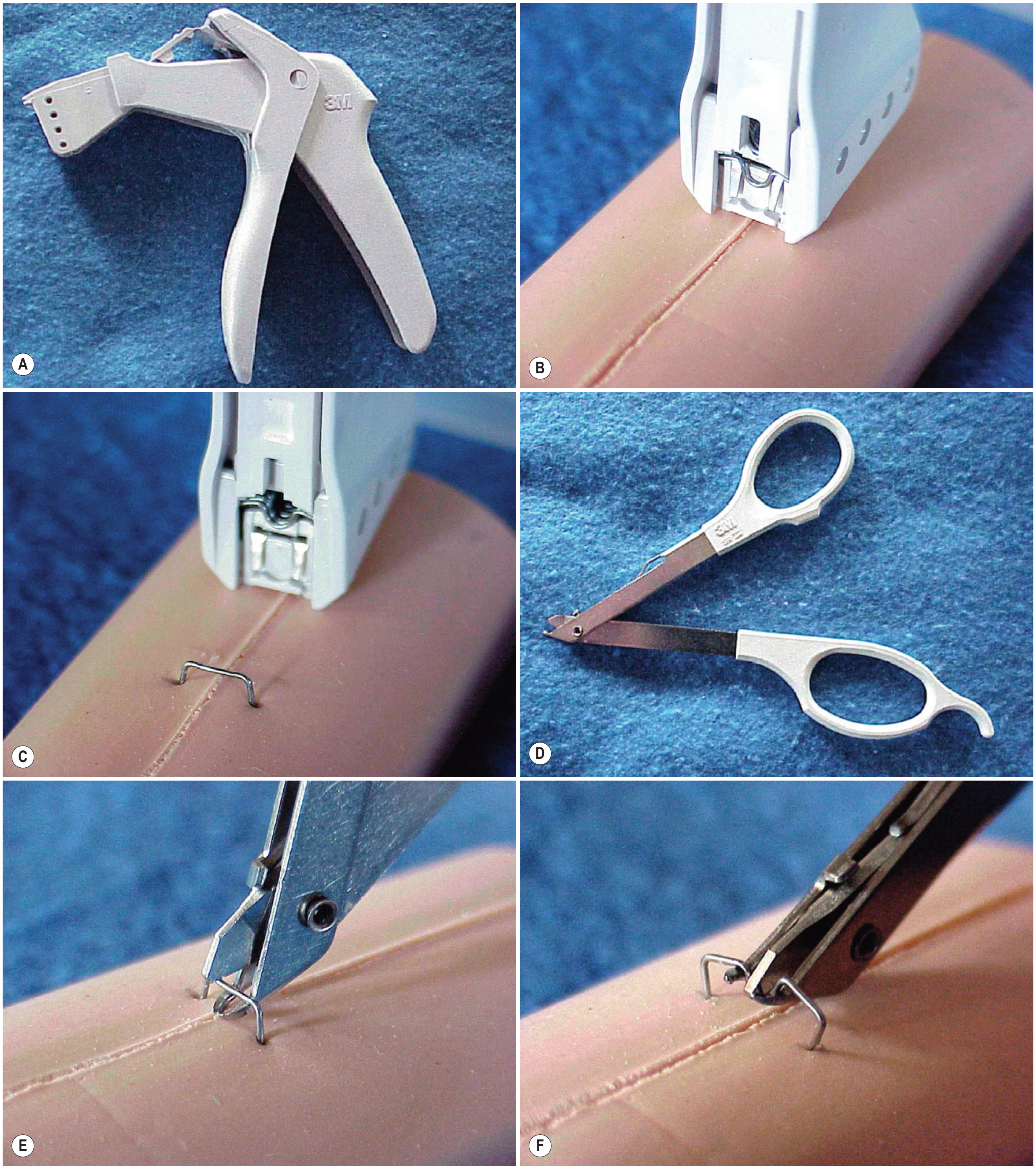

Figure 5.39 Skin stapler. (A) Close-up of skin stapler loaded with multiple skin staples. (B) Single staples may be applied to skin for wound closure. In some cases, it may be useful to have an assistant hold the skin edges in slight eversion while the staples are being placed in the incision. (C) The first staple has been placed and new staple is ready to go. (D) 3M staple removal unit. (E, F) Staple removal unit in action and the staple being removed. This removal process causes little discomfort for most patients.

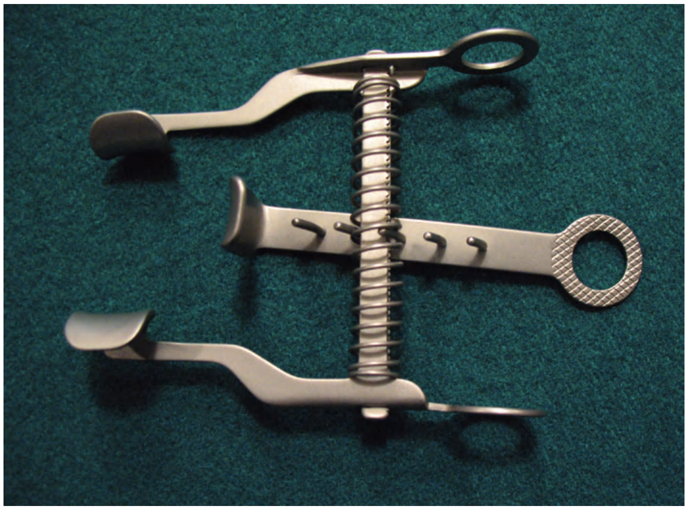

Figure 5.40 Low profile self-retaining wound retractor.

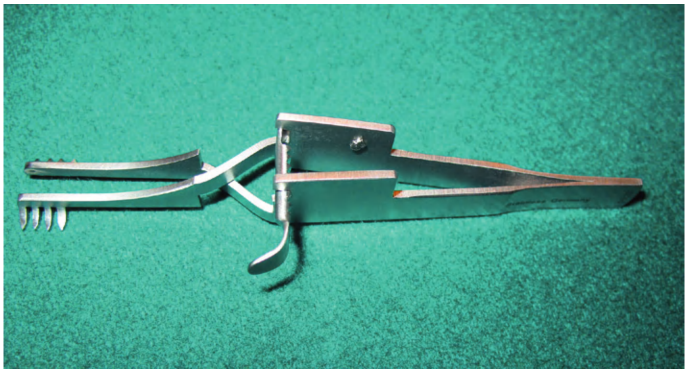

Figure 5.41 Small four-pronged self-retaining retractor.

Figure 5.42 Small Alm self-retaining retractor.

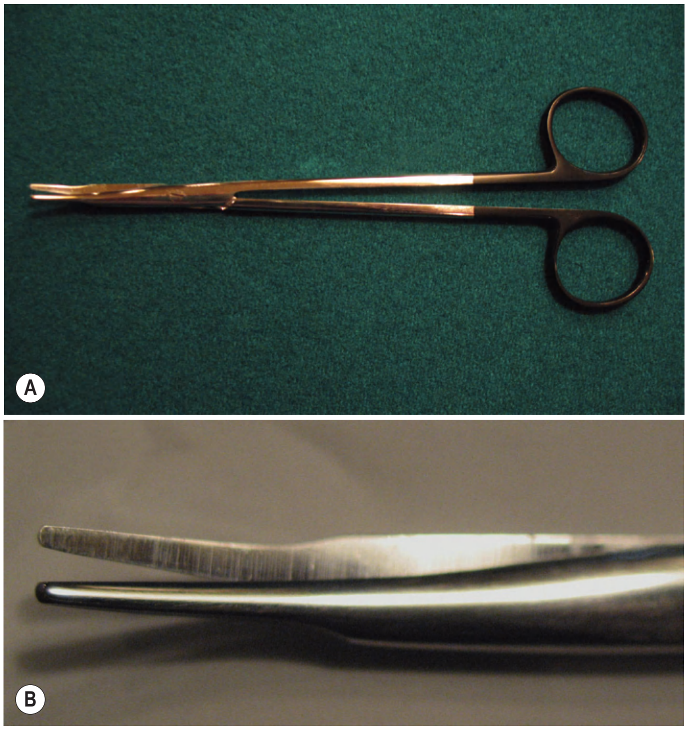

Figure 5.43 (A) Ultra-fine super-cut Jamison scissor. (B) Close-up of ultra-fine scissor tips.

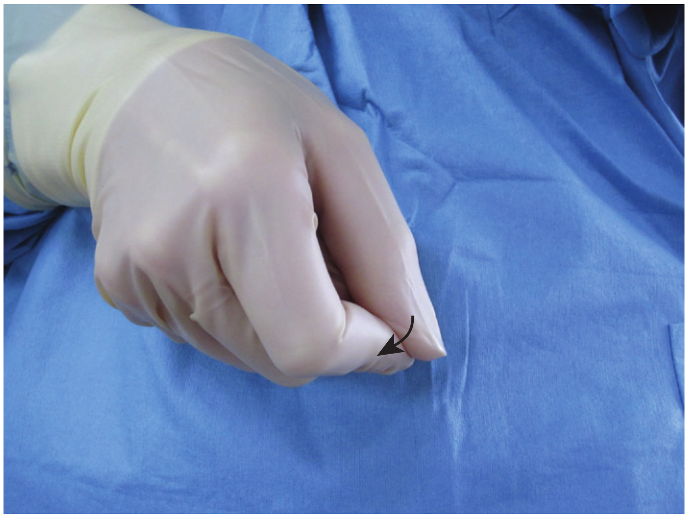

Figure 5.44 Scalpel or knife. The thumb and the first two fingers as the surgeon simulates a cutting motion.