# Amputations Below the Knee

Ernest M. Burgess. M.D.
Joseph H. Zettl, C.P.

AHE elective amputation must be considered plastic and reconstructive in nature. The need to create a dynamic and sensory motor end-organ should be foremost in the surgeon's mind in planning an amputation, and is emphasized here once more. The below-knee stump no longer hangs suspended in an open-end socket. The variable degrees of pressure and weight-bearing over the entire stump surface afforded by the total-contact patellar-tendon-bearing prosthesis enhance the surgeon's opportunity to fashion a functional terminal end-organ. Stump strength created by surgical muscle stabilization; pliable, sensitive, but nontender skin and scar; adequate soft tissue coverage of bone ends and other pressure-sensitive areas; high ligation and division of nerves to remove neuromata from pressure zones; meticulous rounding and tailoring of bone surfaces; all contribute to an ideal organ for substitute limb application. The atrophic, wasted, bony, below-knee stump so commonly encountered in years past is no longer acceptable.

Stump-muscle stabilization, *i.e.*, the attachment of sectioned muscles under appropriate tension to bone (myodesis) and to opposing muscles (myoplasty), is a prime requisite for dynamic stump activity. Muscle stabilization is especially needed in the through-knee and the above-knee amputee. Our experience also justifies its routine use in below-knee amputation. Muscle-to-bone suture does add operative handling of tissues and encircling sutures carry the potential of local muscle constriction. For these reasons myodesis is not recommended for use in the below-knee amputation for vascular disease. The new technique developed by the Prosthetics Research Study utilizes the long posterior myofascial flap sewn anteriorly to anterolateral deep fascia and tibial periosteum and provides a reasonable degree of muscle fixation without risk of strangulation. Muscle-to-bone suture is reserved for the nonischemic patient.

## NONISCHEMIC PATIENTS

The optimum level for a below-knee amputation in the presence of adequate blood supply is at the junction of the middle and lower third of the leg. However, the level of amputation will often be determined by the causal pathology, including infection, the degree of scarring of the tissues, and related factors. The surgeon should save all effective length down to optimum level, consistent with providing a comfortable, nontender stump.

A cylindrical stump shape is desired. The surgeon should think in terms of producing a "foot-like" organ at the below-knee level. The total-contact socket is the "shoe on the foot." Just as plastic surgical techniques are required in operating on the hand and foot, the same techniques of gentleness in skin and other tissue handling are applicable to amputation surgery. When viewed in this light, the amputation becomes a surgical challenge instead of a distressing surgical exercise. Immediate postsurgical prosthetic fitting not only supports and augments the dynamic approach to rehabilitation, it offers certain

[1] Principal Investigator, Prosthetics Research Study, Seattle, Wash., and Director of Amputations and Congenital Defects Service, Children's Orthopedic Hospital, Seattle, Wash. This study was conducted under Contract V5261P-438 with the Veterans Administration.

[2] Director, Prosthetics Research Study, Seattle, Wash.

physical advantages, *i.e.,* immobilization, appropriate continuous pressure relationships, and comfort. These benefits further justify its incorporation into the over-all management of the below-knee amputee.

### AMPUTATION TECHNIQUE FOR THE NONISCHEMIC PATIENT

The patient is prepared for surgery in the usual manner. A pneumatic tourniquet is used. Short, broad fishmouth skin flaps are outlined to provide a mediolateral closure. In the nonischemic patient the flaps are fashioned approximately equal in length. It is advisable to cut the flaps long, then trim them at the time of closure to provide correct skin tension without puckering or undue tension. Skin and fascia are reflected together.

Scarring, infection, deformity, or other unusual circumstances may necessitate modification of the skin closure. Flaps can be outlined to permit closure in any plane or direction provided the resulting scar is nonadherent, nontender, and able to withstand properly and comfortably wearing of a total-contact socket. Anterior location of the scar, condemned in the past, actually is well tolerated even in elderly patients. The application of principles of plastic surgery in skin management must prevail.

In the average adult the tibia is transected 2 1/2 to 3 in. above the distal level of the skin incision. The fibula is divided 3/8 to 1/2 in. higher. A reciprocating power saw facilitates clean bone section. The tibial periosteum is elevated about 3/4 in. above the cut end of the tibia and the anteromedial angle beveled to provide a larger radius on the anteromedial aspect. Careful *rounding* of the edges with a sharp, fine-tooth file is now done. Bone surfaces must be smooth so as to eliminate the possibility of high unit pressures.

When the muscles are to be reattached to bone, a procedure recommended where it is physiologically feasible, 4 to 6 holes not more than 7/64 in. in diameter are drilled through the lateral and posterior periphery of the tibia about % in. proximal to the distal end. Muscles are sectioned long, the gastrocnemius-soleus is left as a myofascial flap sufficiently long to bring it around the end of the tibia to the anterior surface, and nerves and blood vessels are ligated and divided, the former well above amputation level, the latter at the level of tibial section. The nerves are ligated high, as indicated, but are not pulled down so forcibly that traction-avulsion injury results proximal to ligation.

Muscles are now sutured to the bone through the drill holes with medium braided polyester suture and tying the knots within the medullary cavity of the tibia. The loop sutures pass through the body of the major muscle groups and through deep fascia. They should be attached under moderate tension, slightly greater than rest length and therefore capable of providing maximum function. Muscle groups are now sectioned just beyond the end of the tibia except for the gastrocnemius-soleus flap which is left long, beveled, and brought over the end of the tibia as a thinned myofascial flap and sutured to anterior deep fascia and anterior periosteum. Good muscle stability and stump contour are provided by this technique. The moderately bulbous stump will rapidly contour to an ideal cylindrical shape in the rigid postsurgical dressing.

The skin flaps are trimmed and closed with interrupted fine polyester sutures in such a manner that no tension is present, yet a firm stump without redundant tissue is provided (Fig. 1). Drainage of the stump is optional. We prefer a through-and-through Penrose drain; however, suction drainage is convenient and some wounds will not require any drainage.

### THE RIGID DRESSING

The wound is covered with a saline-dampened nonadherent silk or nylon dressing and a small amount of fluffed gauze (2 to 3) is placed over the distal stump end. A sterile three-ply Orion Lycra stump sock is rolled carefully over the stump to avoid damage to the suture lines. The superior portion of the stump sock is held firmly

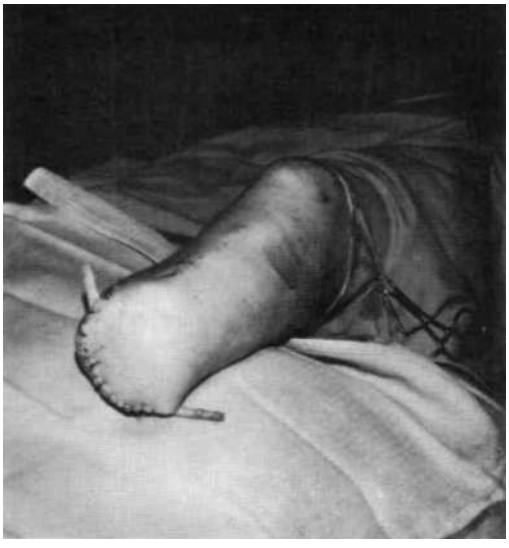

Fig. 1. Below-knee stump of nonischemic patient immediately after closure.

suspended anteriorly and in a proximal direction by an assistant. A simple adjustable shoulder-suspension harness which is interchangeable for right and left can be substituted to achieve the same result.

Relief pads of felt or polyurethane are glued to appropriate locations on the stump sock to provide relief for bony prominences. Prefabricated pads are available in a standard size, right and left, but must be trimmed, skived, and beveled in appropriate areas to suit individual requirements. The pads are designed and located to provide relief of pressures over the patella, the tibial tubercle including the tibial crest, and the distal-anterior (bevel) aspect of the tibia. Dow Corning medical adhesive is used to secure the felt relief pads in place while the polyurethane relief pads are provided with an adhesive backing. A sterile reticulated polyurethane distal pad of the proper size is selected and applied to the distal stump end over the tibial relief pads (Fig. 2).

For the initial part of the rigid dressing, elastic plaster bandage is used because, when pulled within limits of its elasticity, this bandage provides safe and beneficial compression to the stump while conforming well to its contours, providing a smooth, effective, rigid dressing.

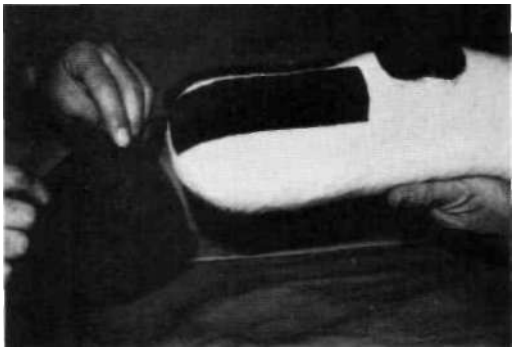

Fig. 2. Application of distal polyurethane pad. Other relief pads are already in place.

Before the wrap is started, the tibial relief and distal relief pads are secured in place with one-and-three-quarter turns of elastic plaster bandage (Fig. 3). Firm tension is applied to the distal portion of the stump from a posterior-to-anterior direction, while the plaster bandage is pulled almost to the limit of its elasticity. By supporting the posterior skin flap, tension on the suture line is reduced and the soft tissues are immobilized. The wrap is then started on the distal end and carried proximally to a level slightly past mid-thigh while tension is maintained in the bandage. A minimum of two layers is required. Circumferential wrapping is carried out from the lateral to the medial aspect, when viewed from the front, in order to avoid anterior displacement of the gastrocnemius

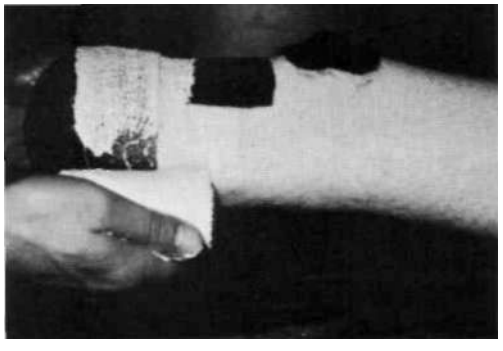

Fig. 3. Beginning the rigid dressing by securing the tibial relief and distal relief pads in place with elastic plaster bandage.

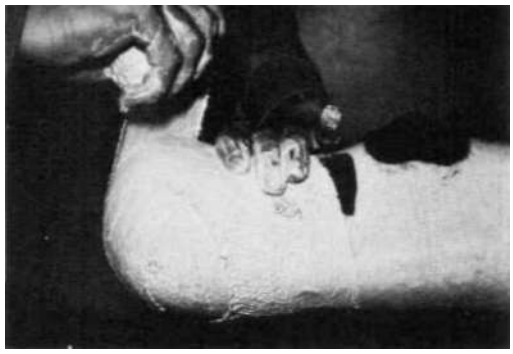

Fig. 4. Application of the first layers of the rigid dressing.

(Fig. 4). Tension in the wrap decreases progressively as the application proceeds proximally to the level of the knee joint where it is simply rolled on up to slightly past mid-thigh. It is important to apply the dressing with firm tension to the distal portion of the stump and to avoid proximal constriction to blood flow. The knee is held in 5 to 15 deg. of flexion controlled by longitudinal tension applied to the stump sock from the proximal end. Owing to the inherent structural weakness of elastic plaster bandage, the initial wrap must be reinforced with conventional plaster bandage and splints. Two splints are applied over the distal portion of the rigid dressing.

A minimum of two layers of conventional plaster bandage is applied starting at the distal third and wrapping proximally with even, overlapping circular wraps (Fig. 5). At the proximal border of the cast a suspension strap is incorporated anteriorly. For an obese patient with excessive soft tissue over the thigh, a second suspension strap is applied posterolaterally. With the plaster of Paris still wet, the cast is gently compressed with the base of each hand just proximal to the femoral condyles to provide an effective built-in suspension mechanism.

After the plaster has hardened sufficiently, the contoured waistbelt is applied to the patient and connected to the strap or straps of the rigid dressing. The prosthetic unit is located and attached to the cast with a roll of conventional plaster bandage (Fig. 6). The pylon is sized and cut to correspond to the length of the sound extremity. A window is cut out of the plaster over the patella to insure com-

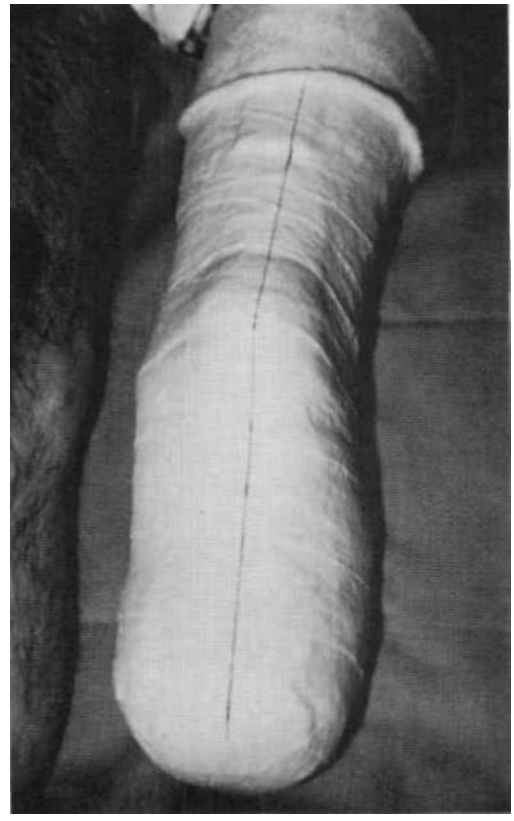

Fig. 5. Completed rigid dressing. Note alignment reference line.

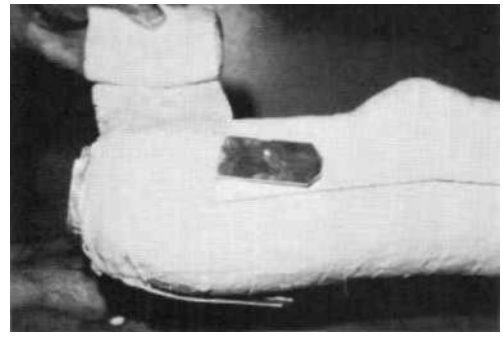

Fig. 6 Attachment of upper portion of prosthetic unit to the rigid dressing. Note alignment reference line.

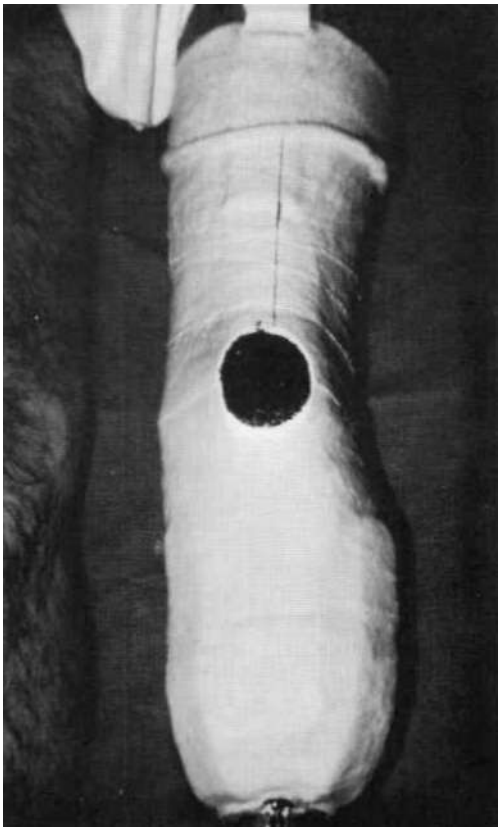

Fig. 7. Window in rigid dressing to provide complete relief over patella,

plete relief in this area (Fig. 7). The prosthetic unit is then disconnected from the cast socket before the patient is taken to the recovery room.

POSTSURGICAL CARE

As a rule, a minimum amount of pain is experienced by patients that have been provided with a rigid dressing. It is unusual for drugs stronger than mild opiates and sedatives to be required for relief. A slight degree of weight-bearing on the stump will usually tend to reduce any discomfort that might be present.

The patient should be encouraged to stand up and bear some weight on the prosthesis as soon after the first 24-hour period postoperatively as is practicable. The time and extent of ambulation must be determined by the responsible surgeon. Walking training should be carried out only under the direction of a physical therapist or other qualified personnel. Activity should be increased daily as the patient's condition permits. Parallel bars, walkerettes, crutches, and canes are used as aids in ambulation. Two bathroom scales may be used to determine the degree of weight-bearing that is taken on the amputated side. These measurements provide a good guide to the clinic team concerning the progress being made by the patient. The patient should never be allowed to ambulate without supervision. Furthermore, ambulation should not be permitted without the prosthesis because in this case the effect of gravity tends to pull the socket away from the stump, thereby reducing the pressure between stump and socket.

On the second postoperative day (48 hours after surgery) the drain is removed. If there does not appear to be any reason for removing the cast, such as elevated body temperature, extreme discomfort, or excessive looseness of fit, the cast is kept in place up to 14 days. If for any reason the cast is removed, whether intentionally or unintentionally, it is mandatory that, if a new cast is indicated, it be applied immediately. During the first two postoperative weeks edema will form rapidly upon removal of the cast and, unless a new cast is reapplied within a very short period, the patient will have to be treated in the conventional manner. The old cast should never be reapplied because of the trauma that is apt to result. When the socket is removed purposely, a cast cutter is used. Often the sutures can be taken out at the time of removal of the first cast, 10 to 14 days after surgery. Sometimes it is necessary to wait until removal of the second cast, 15 to 20 days postoperatively.

In many instances the stump will be sufficiently mature and stable for use of a definitive prosthesis at the time the second cast is removed. When this is so, a cast of the stump is taken and appropriate

measurements are recorded so that fabrication of a permanent prosthesis can proceed immediately. When the definitive prosthesis is delivered, a light plaster socket mobilizing the knee joint is provided for use when the definitive prosthesis is removed. Use of a plaster socket has proven to be superior to elastic bandages to prevent edema. If delays are anticipated in providing the patient with a definitive prosthesis, the prosthetic unit, pylon, and foot are applied to the short cast to continue ambulation activities.

## THE ISCHEMIC PATIENT

Throughout the United States and Canada an estimated 80 per cent of all major, elective, civilian amputations result from ischemia. All but a relatively few involve the lower extremity. Significant advances in surgical and postsurgical management coupled with the use of improved prostheses now allow amputation below the knee in the great majority of these patients.

It is difficult to overestimate the importance of the knee in amputee rehabilitation, especially in the older, classical ischemic patient. Debility, impaired vision, poor balance, neuropathy, compromised circulation and joint function in the remaining lower limb, and chronic systemic illness, all emphasize the critical need to save the knee. The older bilateral leg amputee, especially, needs his knees to approach the rehabilitation goal that permits a reasonable degree of ambulation and self-sufficiency. In a consecutive series of 128 unselected major lower-extremity amputations for peripheral vascular disease (1964 through 1968), we have been able to obtain primary healing at below-knee level in 86 per cent. Once healed, the stumps remain healed. With adequate prosthetic care, secondary breakdown will seldom occur. These patients were among the approximately 300 cases requiring amputation of the lower extremity that were used in studying and developing the techniques of fitting prostheses immediately after surgery. As a result of these experiences, separate surgical techniques have been developed for the ischemic patient and for the nonischemic patient.

### LEVEL OF AMPUTATION

The great achievements in surgical reconstruction of the peripheral vascular system represent a leading chapter in medical progress during the past two decades. Continuing basic and clinical research throughout the world supports the hope that an even higher percentage of limb salvage can be expected in the years ahead. However, despite the practical effectiveness of modern vascular reconstructive surgery, statistics indicate that amputations for ischemia are increasing both relatively and absolutely in relation to population throughout the western world.

When acute or chronic compromise of arterial blood supply reaches a level insufficient to support tissue viability and when reconstructive surgery and nonsurgical supportive measures fail, amputation will be required.

Patients requiring amputation are entitled to comparable medical and surgical consideration, comparable team effort, and the same high-level rehabilitation management attending similar patients whose ischemic limbs are treated by vascular reconstruction. Too often, ablative surgery does not command this high estate.

Decision to amputate may be simple and evident. Gross necrosis of tissue with demarcation, uncontrollable infection, pain, irreversible neuropathy, alone or in combination, and with results of specific tests to assay circulation, will establish the need to amputate. When all available information poses a serious question as to the possibility of limb salvage by reconstructive surgery rather than amputation, it has been common practice to attempt such surgery, even though extensive. Before questionable extensive reconstructive arterial surgery is carried out, the surgeon should consider critically the overriding probability of its failure with mandatory subsequent amputation. Will the proposed surgery compromise the level of amputa-

tion? Will amputee rehabilitation be additionally complicated by further deterioration of general health incident to the extensive surgical attempt at limb salvage? On a number of occasions, below-knee amputations have been performed in ischemic patients who were being considered for possible vascular surgical treatment but in whom, after review of all available information, such surgery might well have damaged the existing blood supply to a degree that an above-knee amputation would then have been required. It is important that the responsible surgeon understand the great rehabilitation value of the knee and weigh all facts relevant to the rehabilitation potential.

There is no single test or combination of tests now available that will demonstrate specifically the lowest effective amputation level. Successful below-knee amputations have been obtained repeatedly in patients whose arteriograms indicated complete occlusion of the superficial femoral artery.

A careful physical examination is the first requisite in determination of the level of amputation. Appearance of the soft tissues, temperature of the skin, the presence or absence of edema after elevation, growth of hair, level of sensation and acuity, together with palpation of pulses, are all important and cannot be supplanted by laboratory data. Arteriography, plethysmography, thermography, and a number of other objective techniques are useful. These include skin mapping with interarterial fluorescein, the use of radioactive Xenon #133, and transcutaneous ultrasonic Doppler recordings. Each adds to the available information and assists in level determination. Old established guidelines for determining amputation level are not valid when weighed against recent experience.

Unless it is *clearly evident* that a through-knee or above-knee amputation will be required, the surgeon should prepare the leg for both below-knee and above-knee amputation. Incisions through the skin and muscle preparatory to below-knee surgery can then be carried out quickly.

Bleeding and tissue viability can be observed directly and the final decision can now be made as to the level of amputation. Only a few minutes are added to the operative time should one elect the above-knee or through-knee level.

### AMPUTATION TECHNIQUE FOR THE ISCHEMIC PATIENT

No tourniquet is used. The leg is draped free with the patient supine. Open and infected areas are walled off and shielded by sterile adherent plastic drapes prior to skin preparation. The level of amputation is 3-1/2 to 5 in. below the knee, *i.e.*, a short below-knee stump (Fig. 8). It has been recognized for many years that skin over the posterior leg has better blood supply than that anterior and anterolateral, and a long posterior and a short anterior skin flap are now used routinely. A long anterior flap, or even equal anterior and posterior flaps, should be avoided. The anterior scar resulting from use of a long posterior flap poses no problem in fitting the prosthesis. The modern total-contact below-knee prosthetic socket can accept a stump with scar placement in any position, provided it is nonadherent, well-healed, and nontender, and it is now standard policy in the Prosthetics Research Study to place the scar wherever it will heal most advantageously.

The anterior skin flap is fashioned approximately at the level of anticipated tibial section. The posterior flap must then be 5 to 6 in. longer to provide proper skin coverage without undue tension (Fig. 9).

After outlining the skin flaps, dissection is carried down through the deep fascia to the tibia. The periosteum is incised and stripped proximally 1 in. The anterolateral muscles are divided down to the intermuscular septum; blood vessels and nerves are ligated appropriately and severed; and then the tibia and fibula are sectioned, preferably with a power saw. The fibula is cut no more than 3/8 to 1/2 in. above the level of the tibia. Soft tissues are dissected from the posterior aspect of

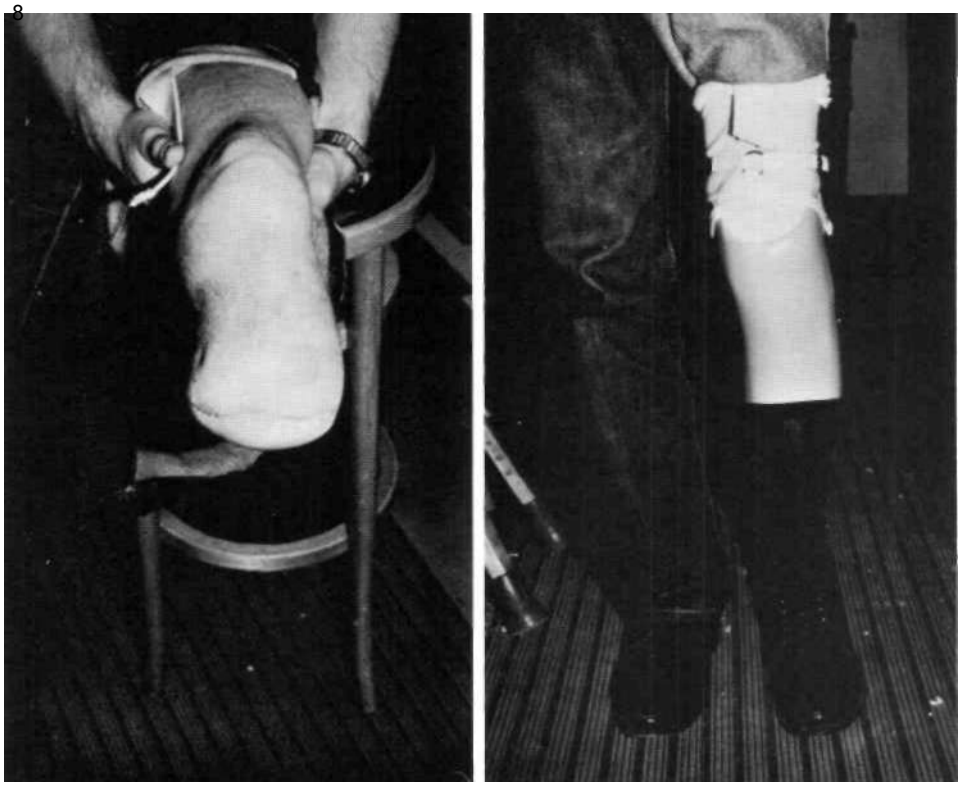

Fig. 8. *Left,* stump of 33-year-old patient on 26th day after amputation because of infection owing to nonunion of the tibia. *Right,* permanent prosthesis provided same patient on 26th day postoperative.

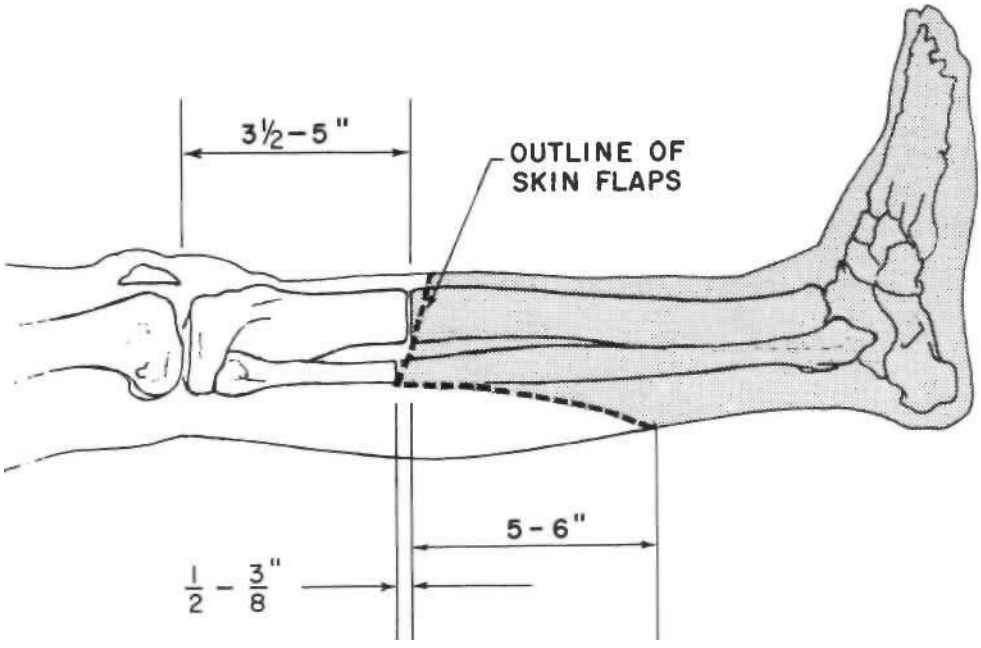


Fig. 9. Outline of skin flaps for below-knee amputation on typical ischemic patient,

the tibia and fibula down to the level of the posterior transverse division of skin. The leg is then separated and removed. The tibia is very carefully rounded with a short bevel over its anterior and medial aspects. It is important that no rough bone areas or ridges remain. A long bevel is specifically avoided. Nerves are pulled down and sectioned high with a sharp knife. They are not injected, crushed, or cauterized. The major nerves are ligated with a fine suture just above the site of division before the division is made. Encircling suture controls oozing from the blood supply that accompanies the nerve, and it also appears to localize neuroma formation and to lessen overgrowth and adherence to adjacent structures. The posterior muscle mass consisting of the gastrocnemius-soleus and deep flexor group is now beveled and tailored to permit the entire muscle flap to come forward and be sewn anteriorly to the deep fascia of the anterolateral muscle group and to the reflected periosteum over the anterior tibia. Contouring and trimming of the gastrocnemius medially and laterally gives a smooth musculofascial flap stabilized over the end of the bones. The skin is then brought up and closed without subcutaneous suture (Fig. 10). Medial and lateral "dog ears" are contoured moderately. They should not be taken back sufficiently to disturb skin circulation. The immediate postsurgical socket rapidly shapes the stump including moderate skin irregularity at the medial and lateral angles. The wound is drained deep to the muscle flap, *i.e.,* to bone. Through-and-through drain or suction drainage may be used. An immediate postsurgical rigid dressing and prosthesis are then applied.

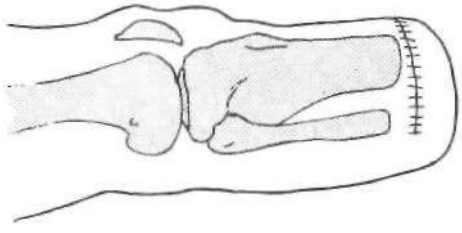

Fig. 10. Below-knee stump of typical ischemic patient showing position of suture line.

POSTSURGICAL CARE

Drains are removed 48 hours after surgery. If the patient's general condition permits, ambulation with guarded weight-bearing is begun 24 to 48 hours following surgery. The advantages of upright activity with limited stance and gait are obvious. However, only touch-down weight-bearing not exceeding 25 lb. is allowed until the initial cast is changed. Personnel in charge of the patient should be instructed carefully as to their responsibility in preventing the patient from bearing excessive weight or from falling.

The postsurgical management with an immediate prosthesis has resulted in much less pain than previously encountered. Postoperative pain is generally of a diffuse aching type. Complaint of localized pain almost always indicates abnormal pressure and requires inspection of the stump and change of the socket. Unless complications develop, *i.e.,* evidence of infection, excessive loosening of the socket, or severe pain, the initial rigid dressing should be left intact until the time of anticipated suture removal, usually two to two-and-one-half weeks following surgery. The cast is then removed, with the patient under sedation but not anesthesia, the wound is inspected, sutures are removed if indicated, and a new temporary prosthesis is applied. By this time the patient is usually ready for unsupported crutch ambulation and discharge from the hospital. A temporary prosthesis is worn continuously until a definitive limb is provided. Ordinarily the final limb can be fabricated, fitted, and worn four to five weeks following below-knee amputation. Typical ischemic patients are shown in Figures 11 and 12.

Necrosis of skin flaps can result from either inadequate blood supply or undue pressure. If the level of amputation is so low that the blood supply is insufficient to support a below-knee amputation, it will be evident at the initial cast change. The decision then to amputate at a higher

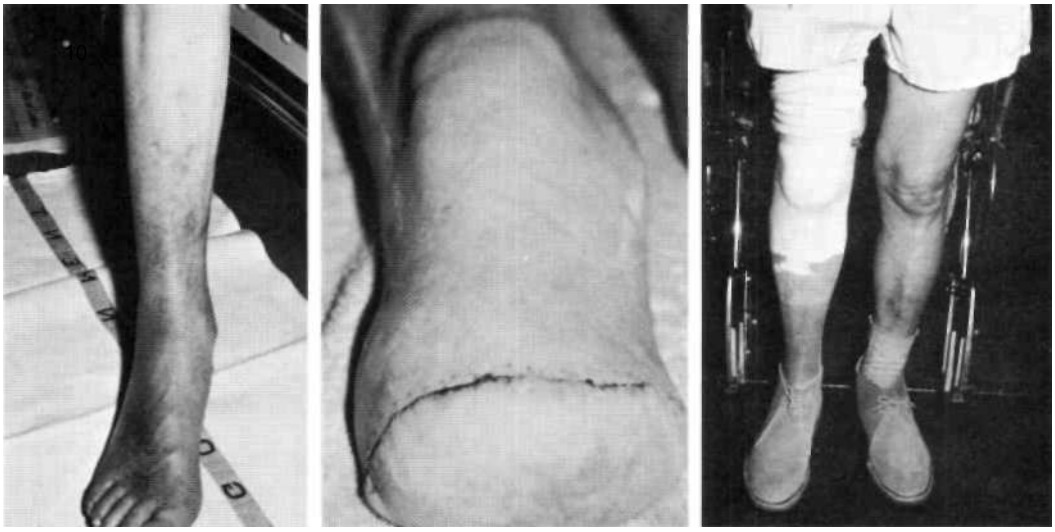

Fig. 11. A 69-year-old, white male had multiple difficulties consisting of arteriosclerosis obliterans with complete right superficial femoral occlusion, diabetes mellitus, arteriosclerotic heart disease with mitral insufficiency, and coronary occlusion. No reconstructive vascular surgery was considered to be feasible. The preoperative condition of his foot is indicated on the *left.* Good stump healing was achieved by the 25th postoperative day, *center.* The definitive prosthesis was applied on the 28th postoperative day, *right.*

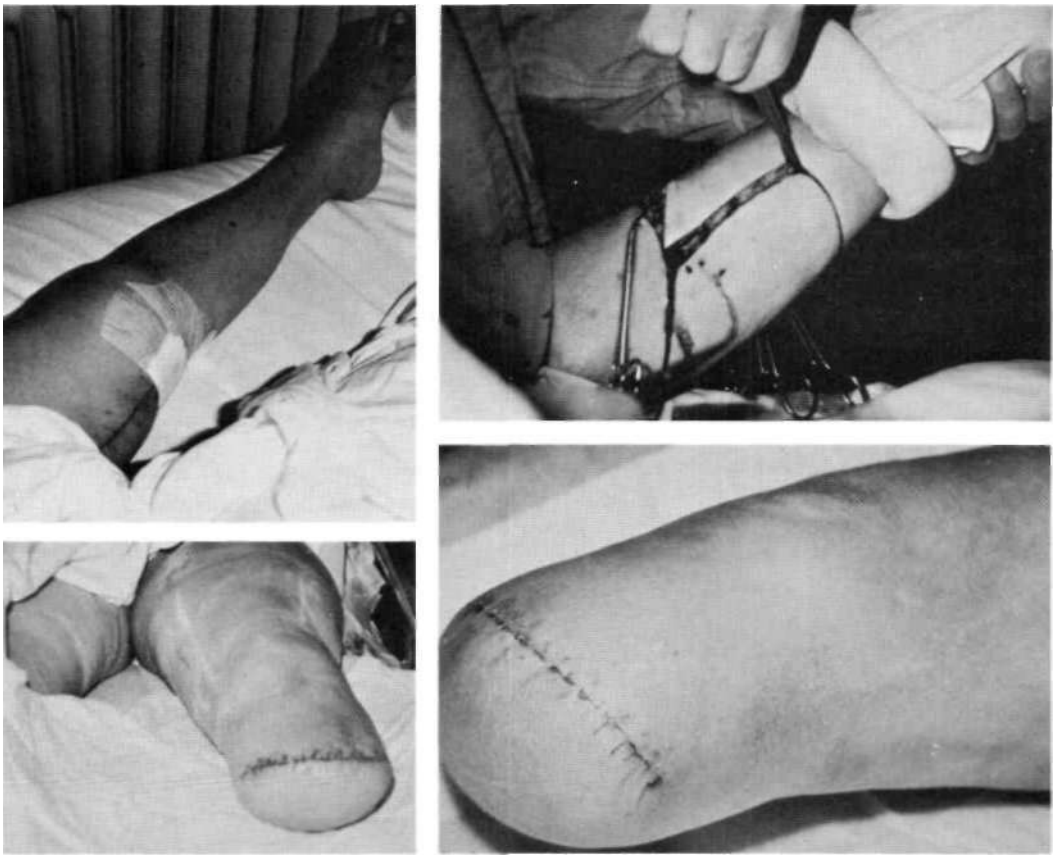

Fig. 12. A 73-year-old, white female with severe chronic peripheral vascular disease without diabetes. Two attempts at femoral popliteal bypass graft had been made in the three weeks prior to "breakdown" of the graft operative sites. Progressive gangrene of the foot had ensued with demarcation just above the ankle level. Figure in *upper left* shows the appearance of the leg prior to amputation. A short below-knee level of amputation was selected and a long posterior musculocutaneous flap developed, *upper right.* The appearance of the below-knee stump at 19 and 29 days following surgery is indicated in the *lower* figures. The definitive prosthesis was fitted on the 32nd postoperative day.

level should be made promptly. Re-amputation rate in the PRS series to through-knee or above-knee over the four-year period has been 9.4 per cent. As experience and techniques have improved, the re-amputation rate for below-knee cases with ischemia has continued to decrease. The surgeon, of course, likes to avoid all re-amputations. However, salvage of the knee is of such paramount importance that an occasional re-amputation may be required if we are to save all knee joints possible in view of our inadequate means for determining the best level for amputation.

## SUMMARY AND CONCLUSIONS

Below-knee amputation is statistically by far the most important major amputation used today. The vast majority of major lower-extremity amputations performed for ischemia will heal primarily and remain healed at below-knee level. The below-knee amputation for ischemia is short in length, the posterior skin and myofascial flaps are fashioned long, and the technique is precise. The resulting stump is cylindrical in shape, well-padded, comfortable, and easily fitted with modern below-knee prostheses of the total-contact type. An immediate postsurgical prosthesis is an integral part of the over-all below-knee amputee management in both the ischemic and nonischemic patient. Restoration of function and rehabilitation of the below-knee amputee, both unilateral and bilateral, have improved in almost spectacular fashion when the guidelines and management which have been outlined are followed.

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