22 Amputations and Rehabilitation

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Abstract

An amputation of the lower extremity is erroneously considered as a failure of conservative care or an unpreventable outcome of diabetes. In the diabetic population, a lower extremity amputation is often the result of ischemia or uncontrolled infection. This chapter discusses multiple factors that should be evaluated to optimize the outcome of any amputation. The technique and important intraoperative factors when performing an amputation are discussed. Following an amputation, a rehabilitation process is begun to return the patient back into the community. Discussed are the factors that influence a patient's rehabilitation potential as a community ambulator.

Keywords

Diabetes • Limb salvage • Transmetatarsal amputation • Below-knee amputation • Rehabilitation

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Indications and Basic Principles of Amputation

Amputation of the foot may be indicated when neuropathy, vascular disease, and ulcerative deformity have led to soft tissue necrosis, osteomyelitis, uncontrollable infection, or intractable pain.

Amputations of the lower extremity are often considered either a failure of conservative management or an unpreventable outcome of diabetes.

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The patient sees amputation as the end of productivity and the start of significant disability. Amputation should be viewed as a procedure leading to rehabilitation and return to productivity for the patient disabled by an ulcerated, infected, or intractably painful extremity. The patient needs assurance, and efforts should be made to follow up the procedure with efforts to return him or her to productive community activity. This may involve consultation among the specialties of medicine, podiatry, orthopedics, vascular surgery, physiatrist, and prosthetics. As the patient is rehabilitated and returns to the activities of daily living, the residual limb and the contralateral limb must be protected. Revision amputation and amputation of the contralateral limb remain significant problems, occurring in as many as 20% of amputee cases [1].

The goal of any limb salvage effort is to convert all patients' diabetic feet, from Wagner grades 1–4, back to grade 0 extremities. Those patients with grade 5 feet will require an appropriate higher level of amputation. If salvage is not feasible, then all efforts are made to return the patient with some functional level of activity after amputation. The more proximal the amputation, the higher the energy cost of walking. This problem is most significant in our patients who have multisystem disease and limited cardiopulmonary function. These factors may negatively impact the patients' postoperative independence.

Patients may require several surgical treatments before definitive amputation. Incision and drainage or open amputation is frequently required to stabilize acute infection. The parameters of healing, to be mentioned later, may not apply at that time. The goal of the first stage of a multistaged procedure is simply to eradicate infection and stabilize the patient. If medical review of the patient suggests an inability to tolerate multiple operations, a higher initial level of amputation may be indicated foregoing attempts at distal salvage. However, if salvage is possible and the patient is medically stable, then a systematic approach to limb salvage should be pursued.

Limb Salvage Versus Limb Amputation

Enlightened orthopedic care of the new millennium has changed focus from results to outcomes. Burgess taught us that amputation surgery is the first step in the rehabilitation of a patient with a nonfunctionally reconstructable limb [2]. He taught us to focus on the reentry of the amputees into their normal activities, setting achievable functional goals.

Lower extremity amputation is performed for ischemia, infection, trauma, neoplastic disease, or congenital deformity. Irrespective of the diagnosis, the following questions should be addressed before either undertaking an attempt at limb salvage or performing an amputation.

1. Will limb salvage outperform amputation and prosthetic limb fitting? If all transpires as one could reasonably predict, will the functional independence of the patient following limb salvage/reconstruction be greater or less than amputation and prosthetic limb fitting? This will vary greatly with age, vocational ability, medical health, lifestyle, education, and social status.
2. What is a realistic expectation of functional capacities at the completion of treatment? A realistic appreciation of functional end results should be made with respect to both limb salvage and amputation. Consultation with physical medicine and rehabilitation, social work, and physical therapy can assist in determining reasonable outcome expectations.
3. What is the time and effort commitment required for both the treatment team and the patient? Both the physician and patient must have a reasonable understanding of the duration of the rehabilitation process, the inherent risks involved with revascularization, and the effort required for both.
4. What is the expected financial cost to the patient and resource consumption of the health care system? Direct expenses of diabetic foot ulceration and amputations were estimated to cost the US health care payers $10.9 billion in 2001 and increase to $116 billion in 2007.

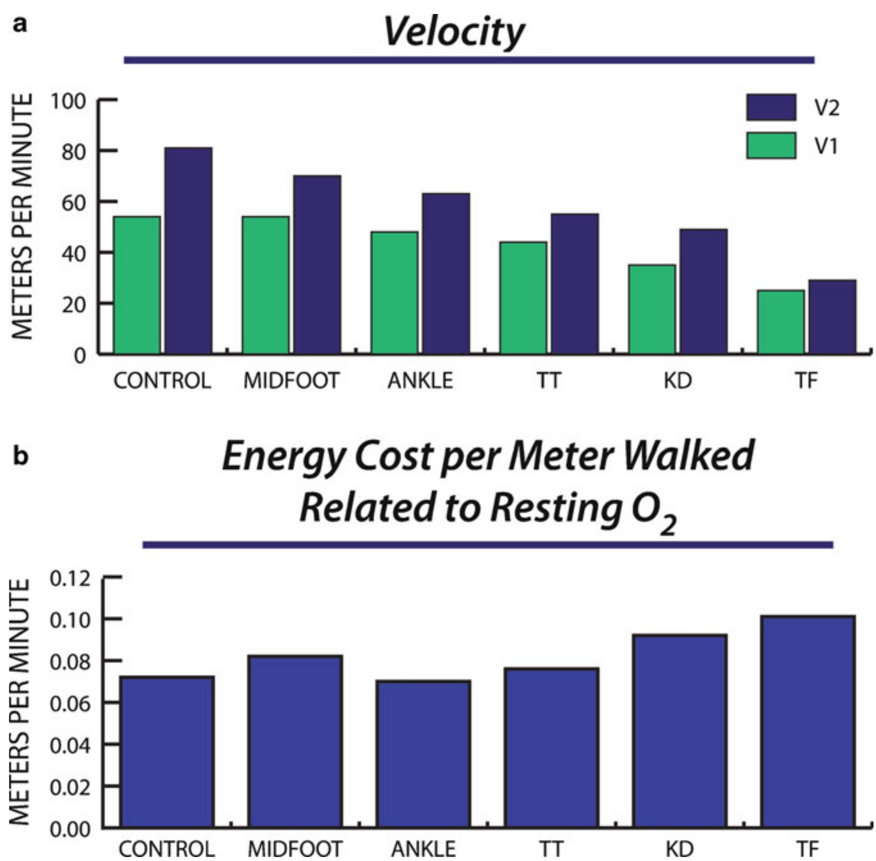


Fig. 22.1 Table of velocity and energy cost. (**a**) Walking velocity compared to surgical amputation level. *V1* is self-selected walking speed. *V2* is maximum walking speed. (**b**) Oxygen consumption per meter walked compared to surgical amputation level. Note that the metabolic cost of walking is increased with more proximal-level amputation

Indirect expense (disability, work loss, and premature mortality) was estimated at $58 billion [3, 4].

Physical and Metabolic Considerations

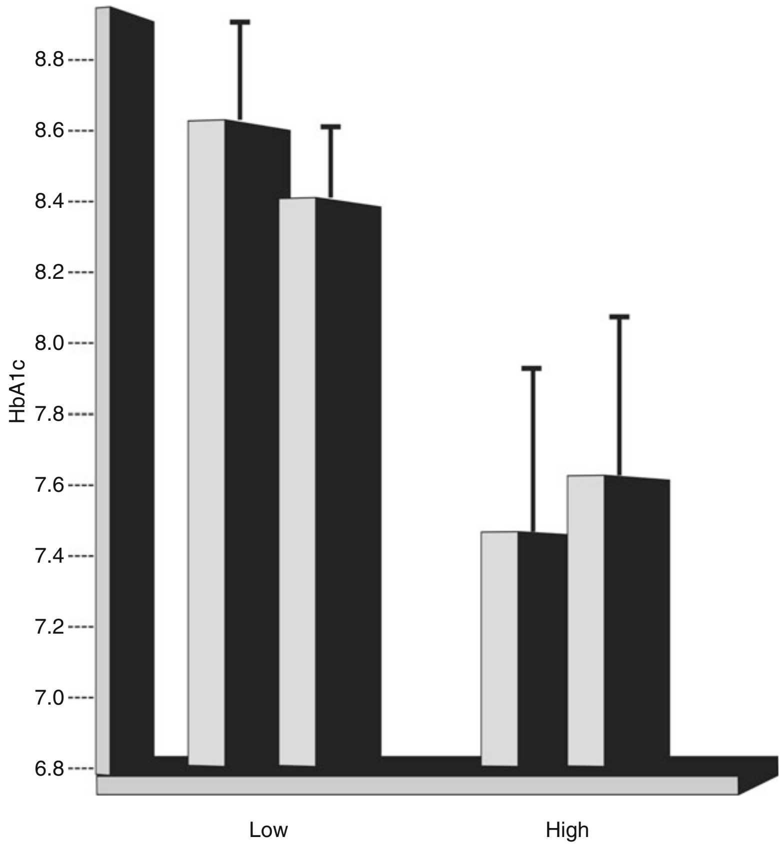
Metabolic Cost of Amputation

The metabolic cost of walking is increased with proximal-level amputations, being inversely proportional to the length of the residual limb and the number of joints preserved. With more proximal amputation, patients have a decreased self-selected, and maximum, walking speed. Oxygen consumption is increased. From an outcomes perspective, functional independence (functional independence measure score) is directly correlated with amputation levels. Distal-level amputees achieve proportionally higher functional independence measure scores (Fig. 22.1) [5–7].

Cognitive Considerations

It is suggested that many individuals with long-standing diabetes have cognitive and perceptual deficits (Fig. 22.2) [8–12]. There are certain specific cognitive capacities that are necessary for individuals to become successful prosthetic users: memory, attention, concentration, and organization. In order for patients with these deficiencies to become successful prosthetic users, they require either specific, successful education and training or the physical presence of a caregiver that can provide substitute provision of these skills.

Fig. 22.2 Cognitive table and higher HA1C. Patients with cognitive dysfunction (CIB ≤ 5 or CDT ≤ 13) had a higher A1C, indicating poorer glycemic control compared with patients without cognitive dysfunction ($P<0.003$ with CIB and $P<0.05$ with CDT). *Grey bar* CIB; *black bar* CDT



Load Transfer and Weight Bearing

Our feet act as uniquely adapted end organs of weight bearing. Following amputation, the residual limb must assume the tasks of load transfer, adapting to uneven terrain, and propulsion, utilizing tissues that are not biologically engineered for that purpose. The weight-bearing surface of long bones is wider than the corresponding diaphysis. This increased surface area dissipates the force applied during weight bearing over a larger surface area, and the more accommodative articular cartilage and metaphyseal bone allow cushioning and shock absorption during weight bearing.

Direct load transfer, i.e., end bearing, which is achieved in disarticulation amputations at the knee and ankle joint levels, takes advantage of the normal weight-bearing characteristics of the terminal bone of the residual limb. The overlying soft tissue envelope acts to cushion the bone, much as the heel pad and plantar tissues function in the foot.

Indirect load transfer, or total contact weight bearing, is necessary in diaphyseal transtibial and transfemoral amputation levels, where the surface area and stiffness of the terminal residual limb require unloading. The weight-bearing load must be applied to the entire surface area, with the soft tissue envelope acting as a cushion [13] (Fig. 22.3).

Soft Tissue Envelope

The soft tissue envelope acts as the interface between the bone of the residual limb and the prosthetic socket. It functions both to cushion the underlying bone and dissipate the pressures and forces applied during weight bearing. Ideally, it should be composed of a mobile, nonadherent muscle mass and full-thickness skin. If the soft tissue envelope is adherent to bone, the shear forces will produce skin blistering, ulceration, and tissue breakdown. It should be durable enough to tolerate the direct pressures and pistoning within the prosthetic socket.

Healing Parameters

Vascular Perfusion

Amputation wounds generally heal by collateral flow, so arteriography is rarely a useful diagnostic tool to predict wound healing. Doppler ultrasound has been utilized to assess blood flow in the extremity before amputation. An ankle-brachial index of 0.45 in the patient with diabetes has been considered adequate for healing as long

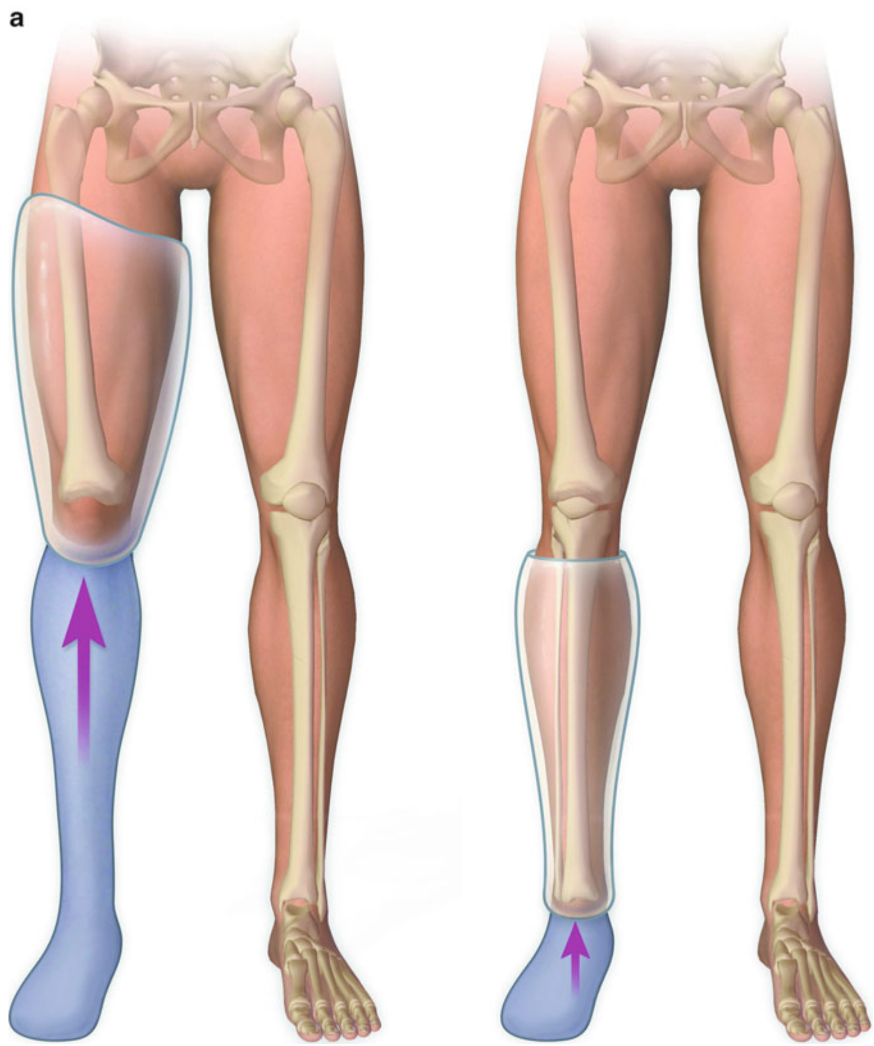


Fig. 22.3 (**a**) Direct load transfer (end bearing) is accomplished in knee disarticulation and Syme's ankle disarticulation amputation levels. (**b**) Indirect load transfer (total contact) is accomplished in transtibial and transfemoral amputation levels

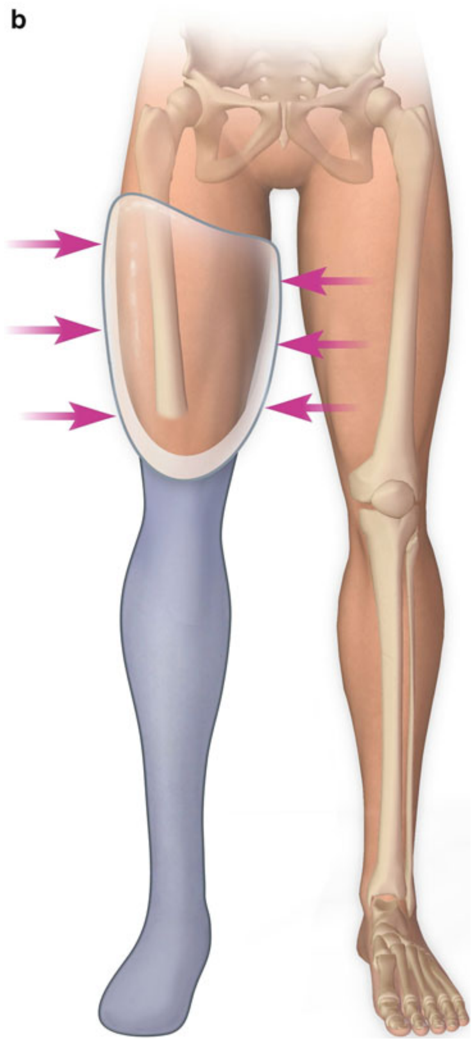


Fig. 22.3 (continued)

as the systolic pressure at the ankle was 70 mmHg or higher. These values are falsely elevated, and nonpredictive, in at least 15% of patients with peripheral vascular disease because of noncompressibility and noncompliance of calcified peripheral arteries [14]. This has prompted the use of varying noninvasive vascular testing modalities, including transcutaneous partial pressure of oxygen ($TcPO_2$), skin perfusion pressure (spp), and toe brachial index (TBI) [15]. Peripheral vascular consultation should be obtained for patients who do not have adequate inflow on these exams. The vascular laboratory can measure toe pressures as an indicator of arterial inflow to the foot. This is owing to the observation that arteries of the hallux do not seem to be calcified, as do the vessels of the leg [16–19]. The accepted threshold toe pressure is 30 mmHg.

Nutrition and Immunocompetence

Preoperative review of nutritional status is obtained by measuring the serum albumin and the total lymphocyte count (TLC). The serum albumin should be at least 3.0 g/dl and the TLC should be greater than 1,500. The TLC is calculated by multiplying the white blood cell count by the percent of lymphocytes in the differential. When these values are suboptimal, nutritional consultation is helpful before definitive amputation. If possible, surgery in patients with malnutrition or immunodeficiency should be delayed until these issues can adequately be addressed. When infection or gangrene dictates urgent surgery, surgical debridement of infection, or open amputation at the most distal viable level, followed by open wound care, can be accomplished until wound healing potential can be optimized [20–23]. At times such as with severe renal disease, the nutritional values will remain suboptimal and distal salvage attempts may still be pursued, but at known higher risk for failure.

Poor glycemic control has been identified as a risk factor associated with a higher frequency of amputation (Fig. 22.4) [24, 25]. High glucose levels will deactivate macrophages and lymphocytes and may impair wound healing as well as having been associated with other postoperative infections including those of the urinary tract and respiratory system. Ideal management involves maintenance of glucose levels below 200 mg/dl [23]. However, caution must be taken in managing the perioperative patient's glucose with calorie reduction, as this process may lead to significant protein depletion and subsequent wound failure. If the patient's BMI is normal, to provide maintenance and avoid negative nitrogen balance, 25 cal/kg is required.

The combined wound healing parameters of vascular inflow and nutritional status have been studied and shown to significantly affect healing rates for pedal amputations. Attempting to optimize nutrition and perfusion preoperatively, when medically possible, will limit the risk of wound complications and failure.

Perioperative Considerations

Pedal amputations may be performed under local or regional anesthesia. The effectiveness of local anesthetics may be impaired by the presence of infection and may need to be administered proximal to any cellulitis. When amputating above the ankle, spinal or general anesthesia will be necessary. Spinal anesthesia is contraindicated in the patient with sepsis demonstrated by fever over 100°F.

Culture-specific antibiotic therapy should be continued perioperatively. If the focus of infection is completely removed with amputation, then the antibiotics may be discontinued 24 h after surgery. If, however, infection remains a concern, then antibiotics are continued for a soft tissue course of 10–14 days, or 6–8 weeks for bone infection.

Tourniquets may be needed to control bleeding at surgery. The surgeon must ensure that the tourniquet is not placed over a vascular anastomosis site or distal to an area of infection. The patient with severe vascular compromise will not require a tourniquet.

Preoperative Summary

Preoperative planning for distal limb salvage procedures should include the measurement of serum albumin, TLC, and tissue perfusion. With satisfactory values in all three categories, healing rates as high as 90% may be attainable. However, at least 10% of even ideal cases may fail. With impaired nutrition or perfusion, the risk of failure becomes even greater. The patient should be informed of these risks. Efforts should be made to use this information to plan procedures at levels that will limit the patient's exposure to multiple revision attempts. A single surgical session for a transtibial amputation may be preferable to multiple futile attempts at distal salvage in severely compromised or borderline cases.

Ray Amputations

Indications

Single toe amputation or ray resection may be performed for irreversible necrosis of a toe without medial or lateral extension. Deep infection of an ulcer to bone is also an appropriate indication for toe amputation. If uncontrollable infection extends to the metatarsal-phalangeal joint or metatarsal head, ray resection is appropriate. This procedure is also useful for infection or necrosis

Comparison between the major amputation and minor or non-amputation groups in each item

Item	Subgroup	Number (n = 210)	Major Amputation Group	Minor Amputation Group and non-amputation group: Minor Amputation Group (n = 65)	Minor Amputation Group and non-amputation group: Non-amputation group (n = 100)	x^{2a}	*p* value
Age at the initial examination[b]	A ≥ 65 years	115	32	37	46	0.002	0.964
	B < 65 years	95	13	28	54		
Sex	A Male	113	37	35	41	2.443	
	B Female	97	8	30	59		0.118
Duration of Diabetes[b]	A ≥ 18.1 years	96	20	37	39	0.496	
	B < 18.1 years	112	25	28	59		0.481
HbA1c	A ≥ 8.0%	94	33	36	25	4.409	
	B < 8.0%	116	12	29	75		0.035 *
Neurological Symptoms[c]	A Yes	165	43	58	64	0.283	
	B No	38	0	7	31		0.595
Retinal Symptoms[c]	A Yes	165	43	58	64	0.139	
	B No	39	1	7	31		0.709
Renal Symptoms[c]	A Yes (with dialysis)	61	30	18	13	7.875	0.0051 *
	B Yes (without dialysis)	96	11	37	48	0.336	0.562
	C No	54	4	10	39		
Dialysis[b,c]	A ≥ 6 years	38	22	9	7	3.379	0.053 *
	B < 6 years	22	7	9	6		
ASO (number of cases)[c]	A Yes (with multiple lesions)	71	39	20	12	10.1	0.0015 *
	B Yes (without multiple lesions)	79	5	37	37	1.918	0.1661
	C No	47	1	8	38		
Ishemic Heart Disease	Yes	64	28	21	15	2.517	
	No	143	17	44	82		0.1126

[a]Difference in the amputation rates determined by the log-rank test between subgroups fromed by Kaplan-Meier method
[b]Subgroups classified by median value
[c]Some cases are unclear or lacking data
* Significant difference

Fig. 22.4 Glycemic table and higher frequency of amputation of the toe, requiring more proximal resection to obtain viable wound margins.

Ray resection is an excellent method of decompressing deep fascial infection limited to one compartment of the plantar structures of the foot, be that medial, lateral, or central. In such cases, the wound is always left open to allow continued drainage and resolution of the acute infection. Once stabilized and healing parameters are optimal, the open ray may be followed by a more proximal, definitive procedure [26].

Procedure

First and fifth ray amputations are a wedge resection of the digit and the incision converges along the medial or lateral aspect of the metatarsal, respectively.

Central ray incisions are different from those of the first and fifth rays. Incisions are made on the medial and lateral aspects of the base of the digit and extend proximally on the dorsal and plantar aspects of the foot to converge over the individual metatarsal. If ulceration is present, as frequently occurs plantar to the metatarsal head, the ulcer is resected along with the wedge of soft tissue that includes the affected toe. The initial incisions are carried to bone, and the toe is disarticulated at the metatarsal-phalangeal joint. The periosteum of the metatarsal is reflected as far proximally as necessary down the shaft of the bone in order to assure that the resection is performed at a level of viable, noninfected bone. The bone is usually cut at the proximal diaphysis or diaphyseal-metaphyseal junction. It is rarely necessary to do the extensive dissection required to disarticulate the metatarsal-cuneiform joint.

Once the bone is removed from the wound, the foot is compressed from proximal to distal to assure that there is no remaining ascending purulent drainage. If the flexor or extensor compartments reveal purulence on compression, then they are opened and irrigated to clean out any remaining apparent infection. If the ray resection was performed for metatarsal or plantar space infection, it is left open to allow healing by secondary intention or a delayed primary procedure (Fig. 22.5a, b).

Postoperative Care

The only ray resection that should be closed primarily is that performed for infection localized to the toe, with clearly viable wound edges, and no suggestion of proximal infection. In this case, a gauze dressing is applied and the patient is maintained in a postoperative shoe until healed. A cane or walker is utilized for protected weight bearing.

In cases where the wound is left open, culture directed antibiotics should be administered for soft tissue or bone infection depending on the extent of the infection. Infectious disease service consultation is advisable. The open wound should be treated according to the surgeon's preferred protocol. If there is significant depth and/or drainage of the wound, you may contemplate the use of alginates or a negative pressure system. Packing should be sufficient to absorb excess drainage, but not aggressive enough to interfere with wound contraction. The foot should be protected from full weight bearing during this time with the appropriate gait-assistive device.

Once healing has been achieved, the patient should have a prescription for protective foot gear. If there is evidence of pressure keratosis developing adjacent to the ray resection site, the patient should be seen in clinic as necessary to pare the callus in order to prevent transfer ulceration.

Complications

Persisting infection is rare if the wound was adequately debrided at the time of the ray resection. However, if residual infection is suspected, follow-up surgical debridement should be done. Wound failure may be owing to inadequate healing parameters, such as impaired blood flow or abnormal serum albumin. Such metabolic wound failures may require more proximal amputation to obtain healing.

The most common late complication of ray resection is transfer lesion and reulceration. If pressure keratosis cannot be managed with debridement and prescription shoes, then resection of

Fig. 22.5 (**a**) Plantar third metatarsal head ulcer. (**b**) Dorsal skin incision. (**c**) Patient after third ray amputation. Note that the plantar ulcer was also excised

the remaining metatarsal heads or more proximal amputation may become necessary [27].

Transmetatarsal and Lisfranc Amputation

Indications

The indications for amputation in a diabetic foot include irreversible necrosis of a significant portion of bone or tendon, uncontrollable infection, or intractable pain. If ulceration is present for a prolonged period of time, not responsive to nonsurgical treatment, and is causing significant disability, amputation of the ulcerated part may be a necessary step to rehabilitation. If the amputation is to be at the level of the toes, foot, or ankle, attention should be directed at well-established vascular and metabolic parameters to assure a reasonable chance for healing success.

McKittrick et al. [28] advocated the transmetatarsal amputation in 1949 for infection or gangrene of the toes in diabetic patients. Wagner, in 1977, subsequently recommended this amputation for use in patients with diabetic foot complications [29], advocating preoperative vascular review. He advised that Doppler studies demonstrating an ankle-brachial artery index greater than 0.45 could predict healing of the procedure with 90% accuracy. The authors' group reviewed 64 transmetatarsal and Lisfranc amputations in 1986 [30]. These amputations were performed for gangrene of the forefoot or forefoot ulcers recalcitrant to nonsurgical attempts at healing. Their results indicated that patients with Doppler

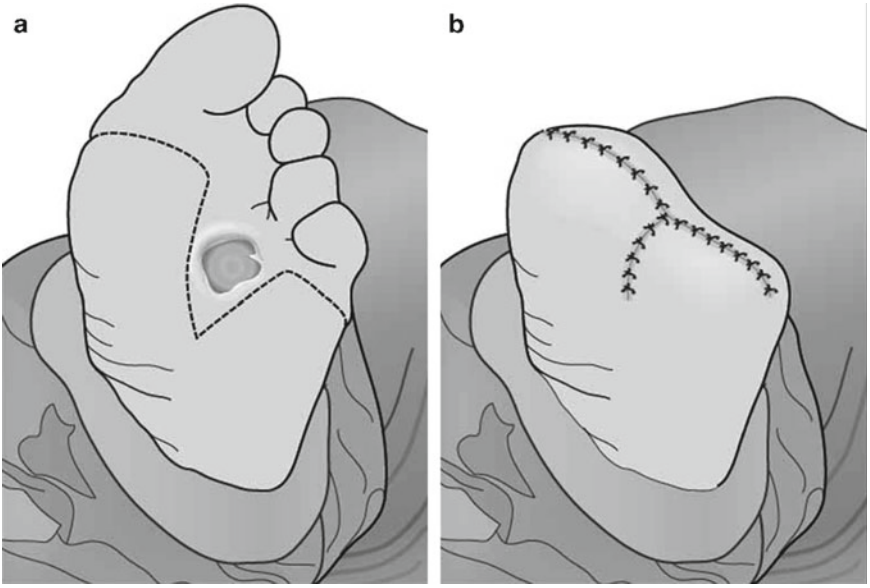


Fig. 22.6 (**a**) The Sanders' technique for plantar flap revision with transmetatarsal amputation in the presence of a distal plantar ulcer. (**b**) The margins of the ulcer site are then approximated with closure as shown

ankle-brachial artery index above 0.5, combined with serum albumin levels greater than 3.0 g/dl and TLC greater than 1,500/cm^3, healed at a rate of 92%. Those patients lacking one or more of these three indicators healed at a rate of 38%.

As stated earlier, amputation of a single toe or metatarsal may be successfully performed for patients with a localized ulceration if preoperative healing indices are satisfactory. However, even if early healing is achieved, there can be significant transfer ulceration following such procedures leading to later complications [26].

This experience suggests that transmetatarsal amputation may be a more definitive procedure for the management of forefoot ulceration. Transmetatarsal amputation may be considered for patients with more than one ulceration or site of necrosis of the forefoot. Likewise, this procedure may be considered in cases with a significant nonhealing ulceration and other foot deformities that are likely to lead to subsequent ulcer. However, transmetatarsal amputation, in itself, does not assure that no further ulceration of the foot is likely.

In our long-term review of midfoot amputations including transmetatarsal and Lisfranc procedures, 9 out of 64 feet sustained new ulcerations within the first year after healing the primary procedure [31]. The source of these ulcerations included hypertrophic new bone formation and subsequent varus or equinus deformity. These dynamic deformities occurred more in Lisfranc amputations, where muscle imbalance was likely to occur because of the loss of the attachments of the peroneals and extensors.

Plantar ulceration under the metatarsals may deter the surgeon from a transmetatarsal amputation, favoring a more proximal, yet more poorly functional, procedure because of the inability to preserve a long plantar flap for closure of the procedure. However, Sanders has demonstrated that a V-shaped excision of the ulceration, with the apex proximal and the base at the junction of the dorsal and plantar flaps, allows conversion of the wound from a simple transverse incision to a T-shaped closure [32]. This produces a longer, ulcer-free flap that can be closed over a transmetatarsal procedure, rather than requiring a more proximal Lisfranc operation to eliminate the plantar ulcer.

The specific indications for transmetatarsal amputation remain similar to McKittrick's, ulcer or gangrene of the toes. Thanks to Sanders plantar flap modification (Fig. 22.6), metatarsal head ulceration is also an appropriate indication for this procedure, when not responding to nonsurgical treatment. Ulceration or infection of a single toe may be treated with an isolated ray resection, understanding a risk of transfer ulceration. If that risk is increased by obvious ulcerative deformity in other parts of the foot, then transmetatarsal or the slightly more proximal Lisfranc amputation becomes more appropriate. All of these procedures are most likely to heal when albumin, TLC, and arterial inflow meet recognized minimal standards described above. Before definitive midfoot amputation, acute infection should be stabilized by incision and drainage, debridement, or ray resection. Residual infected tissue present at the time of the definitive procedure can be expected to compromise success, and should be eliminated in a staged procedure, if necessary. If these criteria cannot be met, then higher amputation may be more appropriate.

Technique

This procedure can be performed with monitored anesthesia care, and spinal or ankle block. General anesthesia is rarely necessary. Appropriate medical clearance should be obtained regarding glycemic management and cardiovascular risks.

The transmetatarsal and Lisfranc amputations differ in technique mainly at the point of detachment of the forefoot from the hindfoot. The transmetatarsal procedure is osteotomized through the metatarsal bases, leaving the insertion of tibialis anterior, peroneus longus, and peroneus brevis intact. The metatarsal osteotomy should be performed through the proximal metaphysis in order to avoid long plantar metatarsal shafts and irregular parabola that might later result in plantar stump ulceration. The Lisfranc amputation requires disarticulation at the metatarsal-cuneiform and -cuboid joints, resulting in loss of the tendon insertions mentioned previously. The writer has made occasional attempts to preserve the base of the fifth metatarsal and peroneus brevis insertion, but this is not always practical.

The procedure begins with a dorsal incision across the metatarsal bases, from the medial to the lateral side of the foot, deferring the plantar incision for the time being. If no tourniquet is used, staging the incision like this avoids dealing with bleeding from both the top and bottom of the foot at the same time. The incision is carried to bone through the dorsal tendons and neurovascular structures. Significant vessels, such as dorsalis pedis, are identified and ligated. The periosteum of the metatarsal bases is incised and reflected using an elevator to expose either the site of the intended osteotomy or the metatarsal-tarsal articulation.

If a transmetatarsal amputation is to be performed, the osteotomies are now initiated. Using a power saw, the first metatarsal is cut, directing the plane slightly medially and plantarly. The second, third, and forth metatarsals are cut, taking care to produce a smooth parabola, leaving no residual metatarsal particularly longer than the adjacent bone. The fifth metatarsal is cut last, directing the plane slightly lateral and plantar. At this point, the plantar incision is made, initiated at a 90° or less angle to the dorsal incision, carried distally to the sulcus, around the metatarsal heads, and then posteriorly along the lateral side of the foot to the fifth metatarsal base. The incision should be carried to bone as much as possible. If plantar metatarsal head ulceration is present, it should be excised using a V-shaped wedge, directing the apex proximally and the base distally at the level of the distal transverse incision. When this is closed, it results in a T-shaped flap.

The metatarsals may now be lifted from the plantar flap from proximal to distal, dissecting along the metatarsal shafts in order to preserve as much of the soft tissue structures in the plantar flap as possible. The remaining distal attachments of the metatarsal heads are cut, and the forefoot is removed. Significant vascular structures should be ligated. The entire wound should be thoroughly irrigated. Remaining fibrous, ligamentous, and exposed tendinous structures should be cleanly cut from flap. Minimal debulking of the remaining intrinsic muscle structures may be

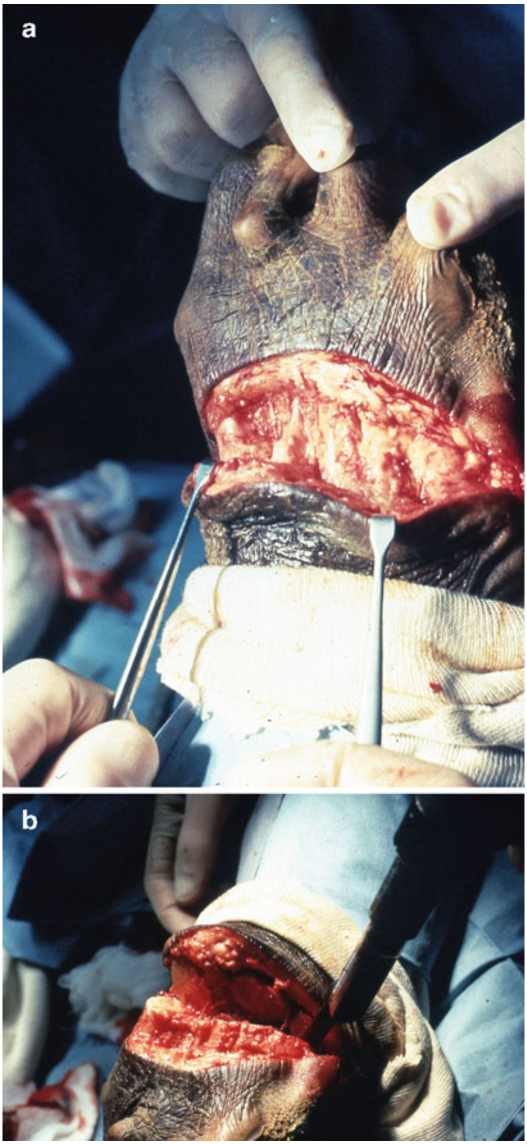


Fig. 22.7 (**a**) Dorsal incision with exposure of metatarsal. (**b**) Proximal metatarsal osteotomies to provide sufficient soft tissue coverage

performed if necessary to obtain approximation. However, as much of the viable tissue of the plantar flap as possible should be preserved (Figs. 22.7 and 22.8).

The technique is similar for a Lisfranc amputation, except that the metatarsal cuneiform and cuboid articulations are detached instead of the metatarsal osteotomy. The first cuneiform is invariably long, and needs to be rongured or cut proximally to a smooth parabola with the remaining metatarsals. This cut should be directed slightly medially and plantarly. Articular cartilage from the remaining tarsals is rongured to bleeding cancellous bone. Since adapting Sanders' plantar flap technique, the writer performs very few Lisfranc procedures because of the obvious functional disadvantage of varus and equinus associated with this procedure. If a Lisfranc is the only option, tibialis anterior is released from the medial side of the first cuneiform and a percutaneous tendo-Achilles lengthening is performed.

Prior to closure, the wound should be thoroughly irrigated. If a tourniquet is used, it should be released and significant hemorrhaging vessels ligated. Because the procedure leaves relatively little dead space, drains are rarely necessary. The wound is closed in two to three layers, starting with sutures placed in the middle of the planar flap musculature and approximated to the intermetatarsal or intertarsal ligamentous structures. Then, subcutaneous sutures are passed from the distal deeper layers of the flap to the dorsal retinaculum. Finally, the skin is closed with mattress or simple interrupted sutures of 3–0 nylon as needed to obtain a satisfactory incision line.

Postoperative Care

Mild compression and protection of flap from tension are the writer's objectives in immediate postoperative wound care. In order to accomplish this, a soft gauze roll dressing is applied from the foot to the ankle. Moderated compression is applied, with minimal force directed from plantar to dorsal in order to protect the plantar flap from undue stress on the incision line. Then, two to three layers of cast padding are applied from the foot to the tibial tuberosity, maintaining the foot and ankle in neutral position, neither dorsiflexed nor plantar flexed. Finally, several layers of 5×30″ plaster of Paris splints are applied posteriorly from the tip of the residual foot to the calf, distal to the knee. The splints are wrapped

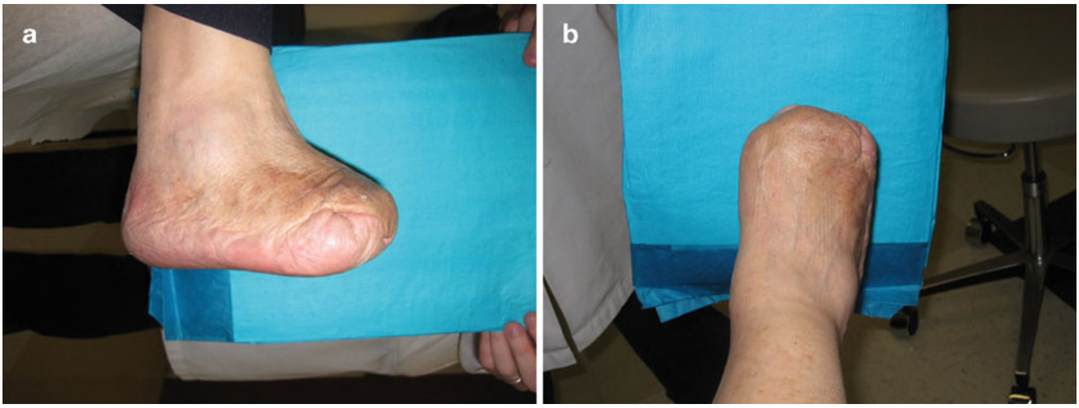


Fig. 22.8 (**a**, **b**) Healed transmetatarsal amputation without equinus, lateral and DP view

with another two layers of cast padding, and an ace wrap secures the entire dressing. This resembles a Jones dressing, protecting the wound from any contusions and from any dorsal or plantar tension.

This dressing is left in place for approximately 48 h before the wound is inspected. A similar dressing is maintained for 2–4 weeks until the incision line is clearly stable. During this time, the patient is instructed in the use of crutches, a walker, or wheel chair with leg elevation. Little or no weight bearing on the operated foot is allowed until the wound is clearly stable and free of risk of major dehiscence. Occasional superficial dehiscence may occur, especially in high-risk patients. This is treated like any other grade I ulcer with cleansing, debridement, and topical wound care measures until healed. Major postoperative dehiscence, infection, or necrosis of the plantar flap will likely require revision surgery.

Complications

Wagner has stated that distal amputations can be expected to heal up to 90% of the time in diabetics who exhibit adequate circulation as determined by Doppler examination demonstrating ankle-brachial artery index of 0.45 or better [29]. The authors' group confirmed that healing could be achieved in over 90% of patients with diabetes undergoing midfoot amputation if ankle-brachial artery index is over 0.5, serum albumin is greater than 3.0 g/dl, and TLC is over $1{,}500/cm^3$ [30]. However, we have also noted that up to 42% of midfoot amputations may suffer some form of complication, even though the majority may ultimately heal their surgical wounds [31]. The complications include early wound dehiscence and late reulceration, which can be treated successfully to result in limb salvage in most cases. Patients most likely to suffer wound dehiscence include those with marginal vascular indices and low serum albumin. This is especially true in renal failure patients. These prognostic indicators should be taken into consideration in preoperative planning and discussed with the patient. Those at high risk for failure may be better served by a higher amputation more likely to heal with one operation.

Biomechanical abnormality resulting from muscle imbalance can result in dynamic varus, producing lateral foot ulceration. This is particularly true in Lisfranc amputations because of the varus pull of an unopposed tibialis anterior. Tibialis anterior tendon transfer in some cases can successfully treat this. Armstrong and associates [33] noted that bone regrowth after partial metatarsal amputation resulted in a significantly increased risk of reulceration. This regrowth was likely to occur in metaphyseal procedures, in males, when manual bone-cutting equipment was utilized. In our experience, these reulcerations can be treated with aggressive exostectomy of the underlying bone and standard subsequent wound care.

Long-Term Follow-Up Needs

Patients with a history of ulceration remain at high risk for reulceration, even after the foot has been returned to grade 0 by a surgical procedure. The patient who has undergone any form of partial foot amputation should be placed in a high-risk foot clinic for regular follow-up visits. Both short- and long-term complications have been recognized. Even though the benefits of distal limb salvage are well accepted, biomechanical review and management visits must be included in aftercare for the amputation to be successful [34]. Early on, the wound should be protected with a posterior splint or cast and limited weight bearing. Rehabilitation should include crutch or walker training, if feasible. If the patient cannot use gait-assistive devices, a wheel chair with leg lift and instruction in wheel chair mobility and transfer techniques should be provided. These protective measures should be continued until wound is clearly healed.

Later, protective foot care or even a plastazote-lined ankle–foot orthosis may need to be prescribed for adequate protection. Although many patients may function well with an oxford shoe and anterior filler, others may need more elaborate orthotic management. Custom-made short shoes, rocker bottom shoes with a steel shank and anterior filler, or conventional shoes with an ankle–foot orthosis have all been advocated. Each patient should be observed carefully as they return to full ambulation to determine the need for orthotic management. Computer-assisted pressure mapping may be helpful in determining the success of any device in off-loading residual pressure points. If keratotic lesions should develop, these should be considered preulcerative and debrided regularly before ulceration can occur [35–37].

Transmetatarsal and Lisfranc amputations have the benefit of improved function and patient acceptance over higher amputation for individuals suffering from serious forefoot infection, ulceration, or gangrene. However, these operations must be recognized as high-risk procedures. Nevertheless, with appropriate preoperative planning, meticulous surgical technique, protective postoperative care, and long-term follow-up, midfoot amputations can be successful limb salvage techniques for most patients undergoing these procedures.

Chopart Amputation

Indications

Francoise Chopart described disarticulation through the midtarsal joint while working at the Charitable Hospital in Paris in the 1800s [38]. The operation has been thought to have limited applications because the residual foot is susceptible to progressive equinovarus deformity. The Chopart amputation is gaining new favor because the length of the limb is retained and the potential complications of the procedure can be successfully addressed. Combining ankle fusion with hindfoot amputation allows apropulsive ambulation with a modified high-topped shoe [38–41].

Amputation levels are usually chosen on the basis of tissue viability and residual limb function. A Chopart-level amputation may be considered when the longer transmetatarsal or Lisfranc amputation level is not an option because of the extent of forefoot tissue necrosis. Half of all patients undergoing an initial nontraumatic amputation will likely require an amputation of the contralateral limb [42]. As discussed earlier, there is a higher metabolic requirement for ambulation in those patients who undergo more proximal amputations. Therefore, the decision on amputation level should attempt to maximize the patients' mobility and independence by preserving length whenever possible, thus making the Chopart amputation useful in cases where more distal foot procedures are not feasible.

An open Chopart amputation is useful to provide resection of grossly infected forefoot structures, as a stage-I procedure, anticipating a higher definitive procedure, such as a Boyd or Syme's amputation. The open Chopart amputation procedure disarticulates the foot at the level of the calcaneocuboid and talonavicular joints, leaving the articular surfaces intact. The proximal spread of infection may be less likely with the cancellous spaces unopened [43]. During the open Chopart procedure, care must be taken to visualize and resect all necrotic and/or nonviable tissue. Compression of the limb proximal to the open amputation site is done manually to identify purulent drainage from the compartments of the leg. If purulence is expressed with compression, then the affected compartment must be incised and irrigated to provide adequate drainage. Once the acute infection is resolved and the healing parameter indices are suggestive of healing, the open Chopart may be revised to a definitive amputation. If the surgeon anticipates that the acute infection may be stabilized and healing is anticipated at the Chopart level, then care must be taken to retain sufficient soft tissue to provide coverage of the residual foot.

The prerequisite for a definitive Chopart amputation is that the plantar heel pad and ankle/subtalar joint articulations are not compromised [44]. A definitive Chopart amputation is considered if the forefoot infection extends proximal to the metatarsal bases and neither a transmetatarsal nor a Lisfranc amputation can be salvaged. Reyzelman et al. [45] suggest that a Chopart amputation is more advantageous than a short transmetatarsal or a Lisfranc amputation because it does not disrupt the transverse arch of the foot. The disruption of the transverse arch creates an overpowering of the tibialis anterior, tibialis posterior, and gastrocnemius muscle to the peroneus brevis muscle. The muscle imbalance created in the short transmetatarsal or Lisfranc amputation may lead to a varus rotation of the residual foot. A frontal plane rotation of the weight-bearing surface of a Chopart amputation is less likely to occur, unless the calcaneus or ankle is structurally in varus [46]. The Chopart amputation does, however, lead to an equinus deformity because of the unopposed pull of the Achilles tendon. An Achilles lengthening and/or performing a tibialis anterior transfer at the time of the definitive closure may address this.

Technique

The dorsal incision begins from the tuberosity of the navicular extending dorsolateral to the mid cuboid level. The medial and lateral incisions are carried distally to the mid shaft level of the first and fifth metatarsals and continued transversely at this level along the plantar aspect of the foot. These incisions form a "fishmouth" creating a dorsal and plantar flaps. The incisions are deepened to expose the talonavicular and calcaneocuboid joints. The tibialis anterior should be identified and preserved for later transfer to the talar neck. The remaining soft tissue structures are incised to complete the disarticulation of the forefoot from the rearfoot. The articular cartilage of the talus and calcaneus should be resected creating a flush surface when the definitive procedure is being performed. The tibialis anterior tendon may be attached to the talar neck by the surgeon's preferred method. If a tourniquet has been utilized, it is deflated and hemostasis is achieved. Once you have completed deep closure, the skin edges are then reapproximated and secured, ensuring no excessive tension. A drain is necessary only if there is significant loose soft tissue, or if excessive bleeding is anticipated, to prevent hematoma formation. After the surgical site has been primarily closed, the Achilles tendon is lengthened by the surgeon's preferred method to limit later equinus deformity. A sterile compressive dressing and a posterior splint are applied to the lower extremity, as was described for transmetatarsal/Lisfranc amputation.

Postoperative Care

The patient is maintained non-weight bearing in a posterior splint or below-knee cast until the wound is healed for up to 6 weeks if necessary. The Chopart amputee without equinus is capable of ambulating in an extra inlay depth shoe with a forefoot filler but functions best with a polypropylene solid AFO prosthesis with a foam filler [43]. The prosthesis helps to eliminate or minimize the pistoning motion of the distal amputation in a normal shoe. If the Chopart amputee has an equinus, then he or she should be fitted for a clamshell prosthesis (Fig. 22.9 Chopart) [47].

Complications

Infection or wound failure is not a complication specific to the Chopart amputation but is more likely if performed on patients who did not meet the generally accepted vascular and nutritional parameters described earlier. Care must be taken to fashion the flaps to provide adequate coverage for the residual foot without soft tissue being secured under excessive tension, as this may lead to wound dehiscence and/or devitalization. Equinus deformity can still occur even if Achilles lengthening is performed. The development of a plantar ulceration in a plantarflexed residual foot is a common occurrence and may lead to revision surgery. As always, close postoperative follow-up and early intervention may minimize these problems.

In spite of these shortcomings, the Chopart amputation remains useful as an early incision and drainage procedure to stabilize acute infection. It is also useful as a definitive procedure in select cases because of its advantage of limb length and tissue preservation.

Transmalleolar Amputation: The Syme's Procedure

Indications

Hindfoot amputation, to be successful, must produce a reliable result with a long-lasting and functional residual limb. Chopart's amputation at the talonavicular and calcaneal-cuboid joints creates significant muscle imbalance frequently resulting in ankle equinus and ulceration. The Boyd amputation has also been advocated [48]. This procedure involves fusion of a portion of the calcaneus to the distal tibia. The advantage is that the heel pad remains well anchored to the calcaneus. An additional problem becomes evident in attaining union of the tibia to calcaneus. There may also be difficulty in prosthetic fitting.

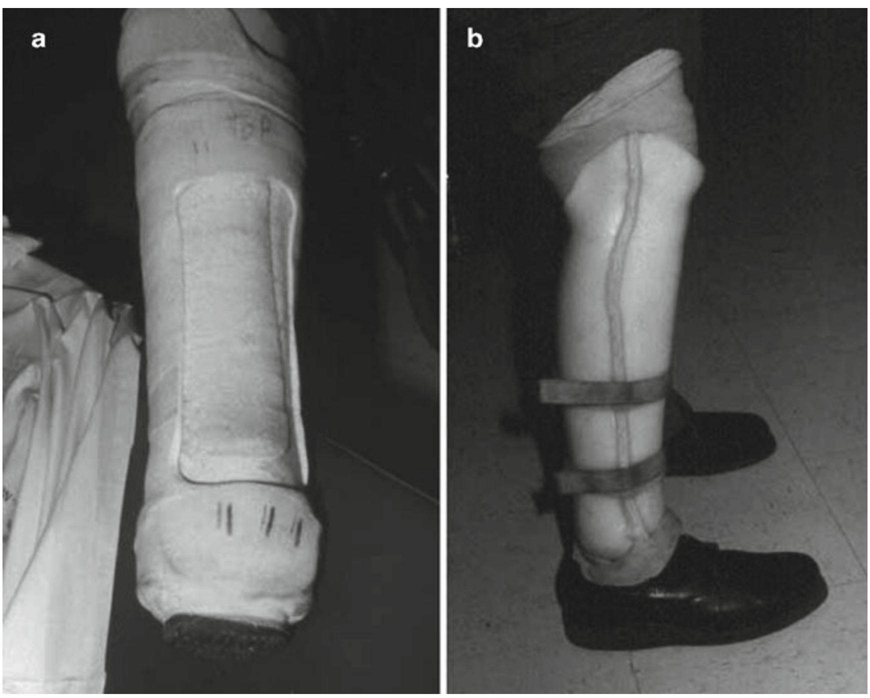


Fig. 22.9 (**a**) A fiberglass cast with a distal rubber bumper and a medial window is used as a temporary prosthesis to allow early ambulation for the Syme's amputation patients. (**b**) A thermoplastic variation of a temporary prosthesis with a prosthetic foot attached. In a patient with very limited ambulation, this may also serve as permanent prosthesis. (**c**) A variety of Chopart prostheses have been advocated. This prosthesis has a posterior closure

c

Fig. 22.9 (continued)

The residual limb remains long and there is inadequate space to place a dynamic-response prosthetic foot without raising the height of the contralateral limb to compensate for this addition. It is unknown whether this height difference results in gait problems for the diabetic patient.

The Syme's amputation is performed through the malleoli and results in physiologic weight bearing throughout the residual limb. The fat pad takes load directly and transfers this directly to the distal tibia [49]. With the use of dynamic-response feet, this amputation level results in decreased energy expenditure with ambulation compared to higher procedures or midfoot amputation [50–53]. Contraindications for this procedure include local infection or gangrene at the level of the amputation, and inadequate nutritional and vascular parameters to sustain distal healing. Healing may achieved using this procedure with serum albumin levels as low as 2.5 g/dl [49]. Heel ulceration has been considered a contraindication to a Syme's procedure in the past. However, an anterior flap may be useful in patients with a nonviable heel pad [52, 54]. A long-term review of this procedure modification in a significant series of patients has not yet been performed.

Procedure

The incision is placed anteriorly across the ankle mortise and then in a stirrup fashion across the anterior heel at the level of the malleoli. The incision is deepened at the anterior ankle and the ankle capsule is incised transversely. The ankle ligaments are released sharply and the talus is displaced anteriorly in the mortise. A bone hook is placed into the talus and used to anteriorly distract the talus so that soft tissues may be freed from the talus and the calcaneus. Care is exercised at the posterior calcaneus to prevent buttonholing of the skin while releasing the soft tissues. Once free, the residual foot is removed from the wound and the wound is thoroughly irrigated. The residual tendons are gently distracted 0.5–1 cm and sectioned. If needed, the anterior ankle vessels may be ligated with appropriate suture. Anterior and posterior margins of the distal tibia may require debridement to diminish excessive spurring. Two drill holes may be placed in posterior tibia and/or the anterior tibia. A heavy absorbable suture (0) may be utilized through the drill holes to anchor the plantar fascia to the distal tibia. The anterior aspect of the residual plantar fascia is sutured into the anterior ankle capsule and the subcutaneous tissues and skin are closed in layers. A medium hemovac drain is placed prior to closure. A posterior splint or a short leg cast is placed. The drain is removed 24–48 h after surgery.

Postoperative Care

The patient may begin assisted/partial weight bearing at 3–5 days and is maintained in a short leg cast for 3–6 weeks. The patient is then advanced to a fiberglass cast temporary prosthesis with a rubber bumper distally. Once the patient's limb has matured and there is minimal residual edema, the patient is fitted for a Canadian Syme's prosthesis with a dynamic-response foot (Fig. 22.10a, b). Full activity is resumed. The need for physical therapy gait training is unusual.

Complications

Healing rates for this level vary from 70 to 80%. Early complications with the wound may occur in up to 50% of the patients. Most of these problems may be treated with local wound care, total contact casting, and culture-specific antibiotic therapy. Other problems include heel pad migration and new bone formation. Heel pad migration has become less frequent with anchoring of the fascia. Should new bone formation become significant or cause ulceration, exostectomy may become necessary [49].

Transtibial or Below-Knee Amputation

Indications

Individuals with transtibial amputation provide the largest population of patients that are capable of achieving meaningful rehabilitation and functional independence following lower extremity amputation. The most predictable method of obtaining a durable residual limb is with a posterior myofasciocutaneous flap [55]. This level takes advantage of the plastic surgical tissue transfer technique of a composite tissue flap without dissection between layers, thus minimizing the risk for devascularization of the overlying skin.

Procedure

The optimal tibial transection level to optimize functional ambulation is a tibial length of

Fig. 22.10 (**a**) A well-performed Syme's amputation with tapered stump and heel pad. (**b**) Syme's prosthesis with and without prosthetic foot

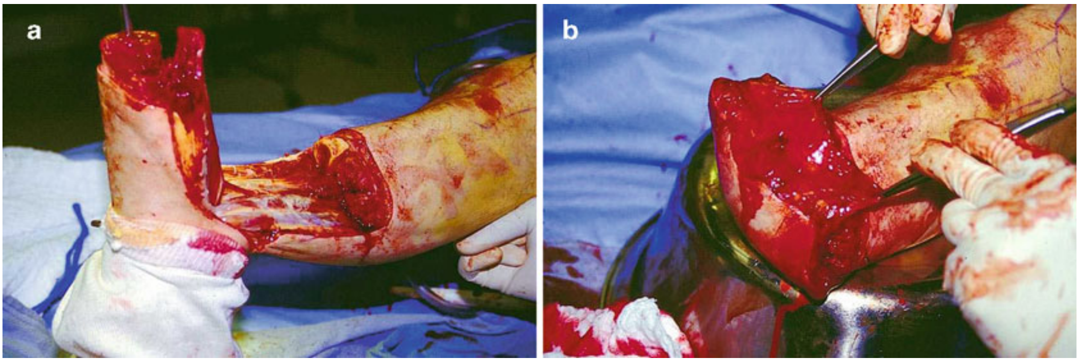


Fig. 22.11 (**a**, **b**) Posterior myofasciocutaneous flap used in transtibial amputation level

12–15 cm distal to the knee joint. The fibular amputation level in the past has been advised to be approximately 1 cm shorter than the tibia. In order to optimize the weight-bearing platform of the transtibial amputation stump, it is now felt that the fibula level should be just a few millimeters shorter than the tibia. The length of the posterior flap should be equal to the diameter of the limb at the level of the tibial transection level, plus 1 cm. A short "fishmouth" should be used on the anterior aspect of the stump to place the surgical scar in a better area for prosthetic fitting. The longitudinal component of the flap should range from one-third to one-half of the width of the limb, depending on the bulkiness of the leg. Thinner limbs with more tenuous blood supply are better performed with a width of approaching 50%, while the amputation stump in obese patients are best created with a width of approximately one-third the diameter (Figs. 22.1 and 22.11a).

The anterior corner of the tibia should be beveled to decrease the shear forces on the anterior-distal aspect of the amputation stump. Historically, the posterior fascia of the gastrocnemius muscle has been sutured to the end of the anterior compartment fascia and the periosteum of the tibia. In order to create a better soft tissue envelope and enhance weight bearing, it is now advised to use a version of the "extended posterior flap" as described by Smith et al. [56]. In this method, the posterior gastrocnemius fascia is sutured to the anterior compartment of the leg and the periosteum of the tibia at a level of 1–2 cm proximal to the bony transection.

Postoperative Care

Postoperatively, a rigid plaster dressing is applied [57]. Weight bearing with a prosthesis is initiated at 5–21 days, based on the experience and resources of the rehabilitation team (Fig. 22.12).

Knee Disarticulation

Indications

Knee disarticulation is generally performed in patients with the biologic capacity to heal a surgical wound at the transtibial level, but they are not projected to walk with a prosthesis [58, 59]. In selected patients, it provides an excellent direct load transfer residual limb for weight bearing in a prosthesis. In limited household walkers or in feeble amputees with limited ambulatory capacity, this level takes advantage of the intrinsically stable polycentric four-bar linkage prosthetic knee joint. The enhanced inherent stability of this prosthetic system decreases the risk for falls in this limited ambulatory population.

Procedure

The currently recommended technique takes advantages of the accepted transtibial posterior myofasciocutaneous flap [60]. The skin incision

Fig. 22.12 Standard below-knee total surface-bearing prosthetic socket and silicone suspension sleeve

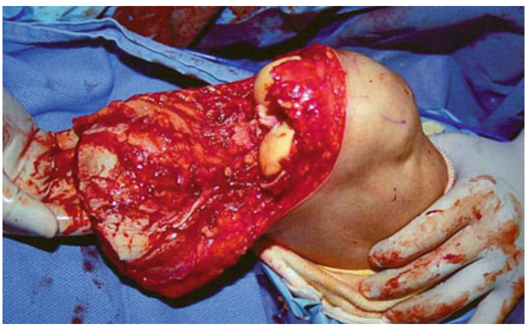


Fig. 22.13 Posterior myofasciocutaneous flap used in knee disarticulation amputation

is made transversely midway between the level of the inferior pole of the patella and the tibial tubercle, at the approximate level of the knee joint. The length of the posterior flap is equal to a diameter plus 1 cm (as with transtibial). The width of the flap again varies with the size of the patient, ranging between the posterior and middle thirds of the circumference of the leg (Fig. 22.13). The patellar ligament is detached from the tibia, and the capsule of the knee joint is incised circumferentially. The cruciate ligaments are detached from the tibia. A full-thickness posterior myofasciocutaneous flap is created along the posterior surface of the tibia. The soleus muscle is generally removed, unless it is needed to provide bulk. The gastrocnemius muscle is transected at the level of the posterior skin incision, with no creation of a tissue plane between the muscle and skin layers. The patellar ligament is then sutured to the distal stumps of the cruciate ligaments with nonabsorbable suture. The posterior gastrocnemius fascia is then sutured to the patellar ligament and knee joint retinaculum retained. The skin is reapproximated by suture or skin staples, and a rigid postoperative plaster rigid dressing.

Postoperative Care

Early weight bearing with a preparatory prosthesis or pylon can be initiated when the tissues of the residual limb appear secure. A locked knee or polycentric four-bar linkage prosthetic knee joint can be used, depending on the walking stability of the patient (Figs 22.14a).

Transfemoral or Above-Knee Amputation

Indications

Gottschalk has clearly shown that the method of surgical construction of the transfemoral residual limb is the determining factor in positioning the femur for optimal load transfer [61]. Standard transfemoral amputation with a fishmouth incision disengages the action of the adductor

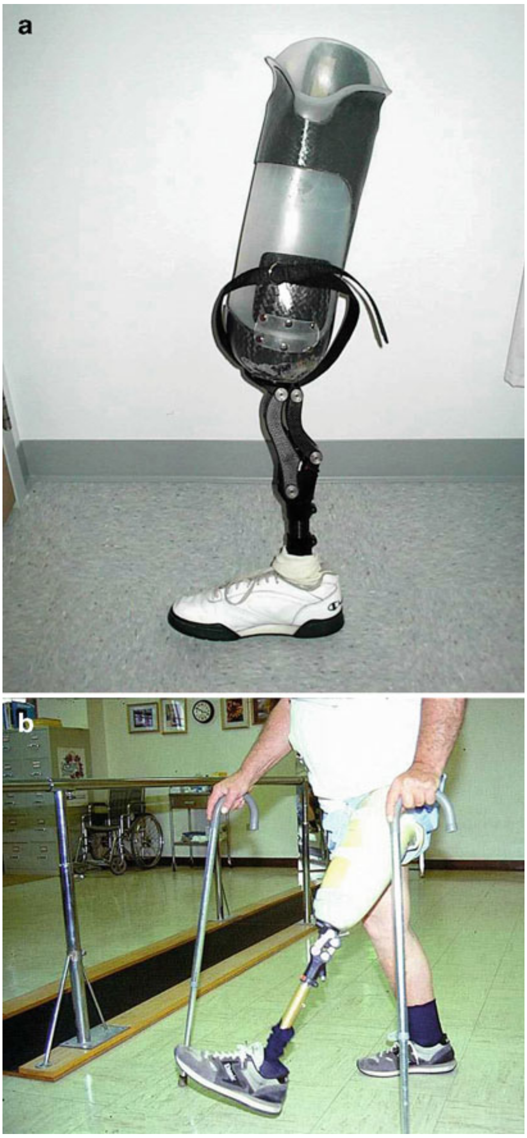


Fig. 22.14 (**a**) Knee diarticulation polycentric four-bar linkage knee joint with preparatory prosthetic. (**b**) Knee disarticulation amputee with polycentric four-bar linkage knee

musculature. By disengaging the adductor muscles, the femur assumes an abducted, nonfunctional position. This relative functional shortening of the abductors produces an apparently weak abductor gait pattern. By using an adductor-based myocutaneous flap, the adductor muscles can be secured to the residual femur, allowing the femur to be appropriately prepositioned within the prosthetic socket [62].

Procedure

In order to accommodate a prosthetic knee joint, the optimal bone transection level is 12–15 cm proximal to the knee joint. The soft tissue envelope is composed of a medial-based myofasciocutaneous flap. The flap, including adductor magnus insertion, is dissected off the femur. After securing hemostasis and cutting the bone, the adductor muscles are secured to the lateral cortex of the femur via drill holes, under normal resting muscle tension. The anterior and posterior muscle flaps are also secured to the residual femur via drill holes. Careful attention is taken to secure the muscles to the residual femur with the hip positioned at neutral flexion–extension so as to avoid an iatrogenic hip flexion contracture, so often produced by repairing the soft tissues with the residual limb being propped on bolsters during wound closure.

Postoperative Care

An elastic compression dressing is applied, and weight bearing with a preparatory prosthesis is initiated when the wound appears secure (Fig. 22.15).

Hip Disarticulation

Few hip disarticulation amputees become functional prosthetic users. Whether sitting in a chair or "sitting" in a prosthetic socket, the weight-bearing platform can be enhanced by retaining the femoral head within the socket.

Rehabilitation

Surgical amputation should be the first step in the rehabilitation of the patient. Thus, the rehabilitation process should be initiated before the actual amputation surgery, whenever possible. The rehabilitation team should have a reasonable expectation of the patients' ultimate rehabilitation potential. When one measures results from an ambulatory perspective or from a measure of achieving activities of daily living, amputees are

Fig. 22.15 Hybrid transfemoral prosthetic socket with modified quadrilateral shape and ischial containment

less functional or independent with more proximal-level amputees. Unilateral ankle disarticulation amputees walk and are functional at a level very comparable to their age and disease-matched counterparts. While 87% of transtibial amputees will be functional walkers at 2 years, 36% will have died [63]. Ambulatory knee disarticulation amputees fare somewhat less well from both ambulatory and independence perspectives. Very few diabetic, dysvascular transfemoral amputees, or bilateral amputees, will become functional walkers.

Regardless of the amputation level, the first step in regaining functional independence is transfer training leading. Many debilitated patients will not have the energy reserves, stamina, or strength to walk with a prosthesis. For these patients, the wheelchair will provide their method of ambulation.

Residual limb care in the early postoperative period can enhance, or detract from, good surgical technique. Specific wound care is related to the circumstances of the surgery. The use of rigid postoperative plaster dressings in transtibial or knee disarticulation amputations controls swelling, decreases postoperative pain, and protects the limb from trauma. The rigid plaster dressing is changed at 5- to 7-day intervals, with early postoperative prosthetic limb fitting and weight bearing being initiated between 5 and 21 days following surgery. Immediate postoperative prosthetic fitting should be reserved for patients with very stable, secure residual limbs. Generally, the residual limb of the transfemoral amputee is managed with a suspended compression dressing. Weight bearing with a prefabricated, or custom, prosthetic socket and training pylon can be initiated when the wound appears secure. With more proximal-level amputation, these multiple system-involved individuals are more likely to require walking aids, with almost all dysvascular diabetic amputees requiring the use of a walker or crutches for their limited range of walking.

Following achieving independence in transfer to the chair, the next step is functional ambulation with gait-assistive devices. The timing of allowing patients to bear weight and start prosthetic fitting will be dependent on the individual patient and the experience of the rehabilitation team. Generally, prosthetic fitting for major limb amputation is initiated at 2–6 weeks following surgery.

When the treatment team develops reasonable, realistic goals, patients are capable of achieving the highest level of functional walking compatible with their multiple organ system disease.

Conclusion

Partial foot amputations are frequently used to successfully accomplish limb salvage. If below-knee or higher amputation is required to achieve healing, many patients return to community ambulation, still utilizing and stressing the remaining limb. Once any form of amputation has occurred, the patient must be considered at high risk for further amputation [32]. The principles of managing any high-risk foot must be applied, and regular review and management services are essential for preserving the salvaged and contralateral limb.

Patient education, shoe review with appropriate prescription or recommendation, and regular professional foot exams are the mainstay of any preventive program [35]. Regular follow-up must be initiated after healing has been accomplished. The patient should be instructed in regular self-foot exams and the effects of sensory neuropathy. Potentially ulcerative pressure points should be identified and accommodated with orthotics and/or shoes as needed. Recurring pressure keratosis should be acknowledged as a potential ulceration, and debrided as necessary to prevent the callus from becoming hemorrhagic or ulcerative. This may require intervals as little as every 4 weeks [33, 36].

It has been the authors' experience that no surgical procedure is effective, in itself, in preventing subsequent foot ulcers. The patient with any form of lower extremity amputation must be considered at high risk for further ulceration. Careful clinical follow-up, orthotic care, and debridement of chronic focal pressure keratosis are far more effective in preventing ulceration or further amputation than any operation.

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