Lower-limb Amputations in Patients With Diabetes Mellitus

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Abstract

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It is estimated that approximately 23.6 million people in the United States have diabetes mellitus. With adequate control of this disease and appropriate foot care and basic surveillance, many patients can lead active and healthy lifestyles. However, some patients experience complications associated with poorly controlled glucose levels, including lower-extremity ulcers and infections. When conservative measures have failed in treating these conditions, a lower-extremity amputation is an option for patients seeking to gain maximal functional recovery. A complete preoperative workup includes assessment of healing potential and preoperative ambulatory status, control or optimization of comorbidities when possible, and determination of amputation level using modern diagnostic modalities.

Once the decision to proceed with an amputation has been made, it is important to choose an appropriate level of amputation and practice sound surgical technique. This article describes the preoperative evaluation and operative techniques involved in performing amputations on diabetic patients and reviews the current literature on the most common lower-extremity amputations performed in the care of infections in the feet of patients with diabetes mellitus.

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Lower-limb amputation is a frequent sequela of deep ulceration with uncontrolled infection in patients with diabetes mellitus complicated by peripheral vascular disease. As the number of patients diagnosed with diabetes continues to increase, the need for interdisciplinary care in performing diabetes-related amputations is becoming increasingly important. According to the American Diabetes Association, approximately 25.8 million people in the United States have diabetes mellitus, and approximately 7 million people are unaware that they have the disease. These latter patients pose the greatest challenge to the health care community because they tend to present with complications of later stages of the disease that require advanced treatment and surgeries.

Approximately 30% of all patients with diabetes mellitus aged older than 40 years have some degree of lower-limb sensory neuropathy. This results in a ten-fold lifetime increased risk of amputation in patients with diabetes mellitus compared with their nondiabetic counterparts. In 2006, sixty-five thousand seven hundred amputations were performed on patients with diabetes, accounting for >60% of nontraumatic amputations performed in the United States. The Fremantle Diabetes Study, designed to unmask risk factors leading to amputation in patients with diabetes mellitus, showed that patients requiring amputation had diabetes for longer durations with worse glycemic control and higher systolic blood pressure. These patients were more likely to have nephropathy, neuropathy, retinopathy, peripheral artery disease, and cardiovascular disease.

Although the cause of foot ulcers is multifactorial, they are generally a consequence of diminished protective sensation from neuropathic disease. Nerves become damaged from poor oxygen delivery due to lack of microcirculation, which results in a loss of myelinated and unmyelinated nerve fibers. This nerve damage leads to a diminished protective sensation in the affected limb. Motor neuropathy can lead to paralysis of the intrinsic muscles of the foot, resulting in claw toe deformities in which the metatarsal heads become prominent plantarly and the proximal interphalangeal joints become prominent dorsally. The skin over these bony prominences may ulcerate from seemingly minor forces, such as those produced by tightly fitting shoes.

**PREOPERATIVE EVALUATION**

It has been consistently shown that the best results of diabetic foot care occur when an interdisciplinary approach is taken toward treatment. Infected ulcers alone are not necessarily an indication for aggressive operative intervention, but once an infection has either proven resistant to local measures or endangers the life and well-being of the patient, amputation may be the next step toward maximal functional recovery. Once the treatment team and patient have decided that operative intervention will likely result in the best outcome, an appropriate preoperative evaluation is imperative.

For an amputation to heal, the patient should have an acceptable nutritional status, including a serum albumin level of at least 2.5 g/dL and a total lymphocyte count of 1500 cells/mm. The patient’s preoperative ambulatory status and comorbidities should also be considered, as well as their cognitive ability and potential for rehabilitation. Taylor et al reviewed the correlation between preoperative clinical parameters and postoperative functional outcomes of patients undergoing major lower-limb amputation and found that patients with limited preoperative ambulatory status, increased age, end-stage renal disease, and coronary artery disease performed poorly with transfibial amputation and recommended palliative transfemoral amputation.

Once these factors have been considered, the operative team must determine the level at which the amputation should be performed to give the patient an optimal functional outcome. Authors have tried to find an ideal method for determining appropriate levels for amputations, and literature describing advantages and disadvantages of more distal levels has been published. However, with advancements in prosthetic design, more proximal levels can gain significant functional results.

Many methods have been described for determining a patient’s ability to heal an amputation site, but the majority of them involve the assessment of distal blood flow. Some methods of evaluation include the presence of palpable pulses, arteriography results, and time to skin bleeding after needle stick or incision, but most of these techniques are unreliable. Vitti et al showed that toe pressures correlated well with the healing ability of a partial foot amputation. Malone et al found that the ankle brachial index, intradermal xenon-133, or absolute popliteal artery Doppler systolic pressure values could not be used as reliable ways to predict whether an amputation wound would heal.

However, they, along with other investigators, found that transcutaneous oxygen levels can be predictive of wound healing and a useful method of level selection.

The current literature describes the minimum requirements for successful healing of an amputation site as an ankle-brachial index of 0.5 and a room air transcutaneous partial pressure of oxygen >30 mm Hg. Several studies show that an increase in transcutaneous oxygen of 10 mm Hg while breathing 100% oxygen in a hyperbaric chamber can also be used as a predictive value for amputation healing. If these parameters are not met, a vascular referral is warranted.

It is common for a patient with diabetes mellitus to present with a systemic infection arising in an ulcer. In this situation, a staged procedure can be used to save the patient from major limb loss or death. The first stage in this approach involves resection at the most distal level to remove all infected tissue. The operative techniques to be discussed do not fully ap-
ply to this stage because the primary goal is an expeditious removal of septic tissue. The operative site remains open while the infection is eradicated with further debridement and broad-spectrum antibiotics. After the infection has been controlled and the patient’s physiologic status is stable, the proper workup can be undertaken and the definitive operative level of amputation selected.

**Surgical Technique**

Regardless of level, a few simple surgical concepts exist that should be practiced routinely. Any amputation technique should maintain a high respect for the soft tissues throughout dissection, amputation, and closure. Unnecessary dissection between the subcutaneous tissue and underlying fascial planes should be avoided to preserve vascularity to the skin. Vessels are identified and ligated, and nerves are transected under moderate tension to allow the proximal end to retract well proximal to the bone end to prevent painful pressure on the inevitable neuromas.

Wound closure and postoperative management are as important as the amputation itself. A closure technique in which no forceps are used and simple sutures are widely spaced should be used. The extra space between sutures is reinforced with adhesive paper strips. No subcutaneous sutures are used; suture of muscle to bone (myodesis) and suture of the fascia are the only deep closures required. Patients with major amputations at or distal to the knee should be casted postoperatively to allow for wound protection and prevention of joint contracture.

**Toe and Ray Amputations**

Infection in patients with diabetes mellitus is the most common cause for partial foot amputation. These procedures allow for near normal weight bearing and gait with prescription shoe wear, which allows patients to maintain a positive body image. All attempts should be made to preserve as much forefoot length as possible while trying to completely excise nonviable, infected tissue. Amputations in the feet of patients with diabetes mellitus require creativity on the part of the surgical team. In the case of infection, it is sometimes impossible to use standard flaps due to nonviable tissue. In these cases, the surgeons must contour nonstandard flaps to obtain low-tension bone coverage in an attempt to maintain length and function. It is imperative that only nonviable soft tissue is resected to ensure a skin flap of sufficient length for wound closure without tension. Soft tissue can be preserved if an initial debridement is undertaken in a prompt manner to ensure that no proximal spread of infection occurs. Another crucial concept is the removal of tissue with poor vascularity, such as tendons, joint capsule, and articular cartilage.

Every effort should be made to preserve the base of the proximal phalanx during great toe amputations to allow for a more normal gait pattern due to the remaining integrity of the flexor hallucis brevis and sesamoids. Disruption of the flexor hallucis brevis and sesamoids may lead to transfer of pressure to the adjacent metatarsal heads. This may be a cause of future ulcer formation and later reamputation. When it is not feasible to preserve the base of the proximal phalanx, the sesamoids and crista should be removed to prevent excess skin pressure from these prominences during stance phase.

Single amputations of the third and fourth toes are typically well tolerated. Resection of toes on either side of the remaining toes leaves them exposed to injury. In the case of ulcers at the end of a toe, the sesamoids and crista should be removed to prevent excess skin pressure from these prominences during stance phase.

In the case of a fifth toe amputation, one may find that a wide metatarsal head may be a source of lateral discomfort and ulceration. This may be treated with a sagittal resection of this prominence. A final option in the case of multiple toe ulcerations is disarticulation of all toes, with removal of the relatively avascular articular cartilage and volar plates.
A ray resection may be a more suitable option when an ulcer is located beneath the metatarsal head. Medial ray resections are not as well tolerated as lateral ray resections (Figure 2).36-39 If it is necessary to perform a resection of the first ray, maximum length of the metatarsal should be preserved in an attempt to prevent a planovalgus deformity by use of a foot orthosis that supports the remaining shaft of the first metatarsal. The metatarsal should be beveled plantarly to avoid abnormal pressure during the toe-off portion of the gait cycle.

Single resections of the second, third, or fourth rays should be performed through the proximal metaphysis to allow approximation of the remaining rays. When resecting the fifth ray, an attempt should be made to preserve the insertion of the peroneus brevis. If this is not possible, it should be transferred to the neighboring structures, such as the cuboid. Any residual of the fifth metatarsal should be beveled with a distal inferolateral facet to help prevent repeat ulceration. If multiple lateral rays are resected, they should be done with a gradual cascade toward the first metatarsal in an attempt to mimic the natural configuration of the foot.30

Transmetatarsal Amputation

When a patient presents with an extensive forefoot ulceration, it is sometimes impossible to eradicate infection without partial resection of multiple rays. A transmetatarsal amputation preserves the insertion of all major foot motors, allowing for a more normal gait pattern with appropriate shoe wear than a more proximal Lisfranc or Chopart disarticulation. Transmetatarsal amputations are sometimes approached with hesitancy due to the high complication rate that has been associated with the procedure.32

Ideally, long plantar and dorsal full-thickness flaps are developed. However, long flaps are not always available in the population of patients with diabetes mellitus due to infection or poor skin perfusion. Another method for developing soft tissue coverage is to make full-thickness flaps plantarly and dorsally as far distal as the conditions will allow. Some creativity is required in cases of larger ulcers. After the appropriate bone resections, these ulcers should be excised and the surrounding soft tissues contoured for a tension-free closure (Figure 3).

The bone resection should mimic the normal cascade from distal–medial to proximal–lateral, with a plantarlateral bevel of the remaining metatarsals. To prevent recurrent ulceration, this procedure should be coupled with an Achilles tendon lengthening, especially if the triceps surae is contracted.40 Postoperatively, patients are placed in a rigid dressing in slight dorsiflexion until the soft tissues have healed.

Data citing the high complication rate associated with transmetatarsal amputations have been published,41,42 Other studies have shown good functional results after this procedure. In a study of factors associated with healing after transmetatarsal amputation, Nguyen et al43 concluded that this procedure is warranted in ambulatory patients to maintain their preoperative functional status. They also associated repeat debridement, history of smoking, and infrapopliteal vascular occlusion with revision surgery due to wound complications. Hosch et al44 found that patients with diabetes mellitus without ischemic conditions were significantly less likely to need revisions to more proximal levels after transmetatarsal amputation. Stone et al45 found a lower mortality rate but a higher revision rate in transmetatarsal amputations when compared with higher level amputations. These studies revealed that transmetatarsal amputation is a valid option in an effort to maintain preoperative functional status as long as the patient is properly educated and is a suitable candidate based on the preoperative factors described, in an attempt to minimize postoperative complications.

Tarsometatarsal (Lisfranc) Disarticulation

When tension-free closure after a transmetatarsal amputation is impossible due to an extensive loss of soft tissue, disarticulation through the tarsometatar-
sutured to the surrounding structures to the base of the first metatarsal can then be fixation. The remaining distal insertions on the medial cuneiform with careful dissection. The remaining distal insertions on the base of the first metatarsal can then be sutured to the surrounding structures to reinforce its attachments. It is also commonly accepted that the base of the second metatarsal should be preserved as the stabilizing structure of the transverse arch, while the other transmetatarsal joints are disarticulated. It is imperative that this procedure be accompanied by measures to reduce the deforming force of the triceps surae, such as by lengthening the Achilles tendon. Postoperatively, patients should be casted in slight dorsiflexion until the soft tissues have healed (Figure 4).

Midtarsal (Chopart) Disarticulation

This procedure is most commonly performed after severe foot trauma and is rarely indicated in patients with diabetes mellitus with an extensive foot infection because recurring infection will prevent salvage at the ankle disarticulation level. It is performed through the talonavicular and calcaneocuboid joints. This disarticulation requires a large plantar flap to allow coverage of the distal calcaneus and talus. Some degree of distal contouring of the bones may be required to remove excessive bony prominences. Loss of the antagonists to the triceps surae, as well as the remaining short lever arm, may result in an inefficient and painful postoperative gait due to a resultant equinus contracture.

Muscle balancing is imperative when performing a midtarsal disarticulation. The tendons of the tibialis anterior and extensor hallucis muscles may be transferred to grooves in the talar head, whereas the common toe extensors can be transferred to the distal calcaneus. Alternatively, the tibialis anterior tendon is attached to the talar head. Any tendon transfers should be paired with an Achilles tendon lengthening or resection. Ideally, this procedure should be protected postoperatively with a rigid cast in dorsiflexion until the soft tissues have healed. Greene and Cary compared the results of forefoot amputations, transmetatarsal and midtarsal disarticulations, and midtarsal disarticulations with an equinus contracture to patients with Syme ankle disarticulations. Their results showed that toe and ray amputations had the best functional outcomes, followed by transmetatarsal amputations and balanced midtarsal disarticulations. Patients with midtarsal disarticulations with an equinus contracture had the poorest functional results (Figure 5).

Ankle (Syme) Disarticulation

In an attempt to maintain distal weight-bearing function while eradicating an extensive foot infection, a Syme ankle disarticulation can be a suitable option. Weight is borne on an intact heel pad, resulting in better function when compared with transtibial amputation. It has also been shown that mortality in patients undergoing this procedure is reduced compared with transtibial amputees. Birch et al found good results in a study of patients who underwent a Syme procedure for fibular deficiencies. These findings were similar to those of Herring et al. The population was younger and healthier than the diabetic population, but they demonstrated that the amputation in itself should not limit activity level.

For this amputation level to be successful, the patient requires a heel pad free...
of infection with a patent posterior tibial artery. Laughlin and Chambers had good results after Syme procedures in patients with diabetes mellitus and found that the ability to heal the amputation site correlated well with preoperative posterior tibial artery Doppler findings. In cases with more distal infections in which ray resections or wound debridements are being considered, it is important that incisions be made as distally as possible to respect the integrity of the heel pad to keep a later revision to a Syme level a viable option.

This procedure should begin with a transverse incision joining points 1 cm distal and anterior to the sagittal midline of each malleolus. The ends of this transverse incision are connected with a plantar stirrup incision placed anterior to the heel pad (Figure 6). It is important that the posterior tibial neurovascular bundle be preserved throughout the procedure. The talus and calcaneus are removed by incising their soft tissue attachments under gentle traction.

The distal tibia and fibula can then be resected 0.75 cm proximal to the tibial articular joint, effectively removing the malleoli. Another option is removal of each malleolus individually, leaving the articular cartilage of the tibial plafond. This is the preferred method because it preserves the weight-bearing articular cartilage and prevents the heel pad from scarring down to the distal tibia simultaneously. The plantar fascia is then sutured to the anterior tibia to secure the heel pad directly beneath the tibia. The Achilles tendon can also be detached and sutured to the posterior tibia to neutralize its pull on the heel pad. Postoperatively, the patient should remain in a series of well-molded casts that hold the heel pad directly beneath the tibia until the prosthesis is fitted. In the past, some controversy existed as to whether this procedure should be staged to ensure healing, but recent studies have shown similar results between 1- and 2-stage procedures, and higher complications and risks were found in with 2-stage procedures.

### Transtibial Amputations

Transtibial amputations compose the majority of all lower-limb amputations and are the level at which all others are typically compared. This level is used primarily when the proximity of the disease process precludes a partial foot or ankle amputation. Some factors that must be considered in making a decision about whether a transtibial amputation will be successful include the patient’s ability to heal their operative site, the presence or absence of a knee flexion contracture, and the preoperative ambulatory status of the patient.

In a study of 277 patients undergoing their first transtibial amputation, Izumi et al found that the risk of amputation in the contralateral limb was greater than 50% after 5 years. Larsson et al looked at the mortality, re-amputation, and rehabilitation outcomes in 189 diabetic patients who underwent amputations for infected foot ulcers. Mortality after an amputation was 68% at 5 years and was greatest after an amputation above the ankle. Sixty-one percent of patients who lived independently before a major amputation returned to their previous status.

Some technical considerations must be made to allow for maximal functional results. The shortest functional stump must include the tibial tubercle with its insertion of the patellar tendon to preserve knee extension. Stump length was traditionally described as no longer than 15 cm to avoid difficulties with prosthetic fitting, but with modern prosthetic designs, the problems with longer transtibial stumps are greatly reduced. An ideal transtibial stump length no longer exists. The decision as to length should be based on clinical findings, preoperative assessment of the healing ability of each patient, and availability of muscle distally to perform a stable myodesis as part of the soft tissue envelope.

The primary goal of flap selection is to allow adequate soft tissue coverage for a tension-free closure, provide a soft tissue envelope for later prosthetic fitting, and avoid scar adhesion to underlying bone. Many techniques have been described, but the most commonly used one in our institution is the long posterior flap. In this technique, the transverse anterior incision begins at the junction of the proximal two-thirds and distal one-third of the leg. The posterior flap is developed at a length equal to two-thirds of the diameter of the leg plus 1 cm. Sharp corners should be avoided to prevent the formation of “dog ears.” All major peripheral nerves should be identified and transected under tension to allow for retraction prevent painful neuromas.

The tibia is cut transversely, and the anterior cortex is beveled and filed smooth. The fibula should be transected no more than 1 cm proximal to the tibia and cut with a posterolateral bevel to prevent abnormal pressure over the distal fibula. The posterior deep calf musculature is then excised at the tibial level to allow for a tension-free closure. Myodesis provides stable distal bone coverage and is accomplished by suturing...
the soleus muscle and its myofascia to the anterior tibia through drill holes. The closure is followed by application of a postoperative cast in extension until the soft tissues have healed. This usually lasts for 3 weeks, with weekly cast changes for wound checks and to allow for knee range of motion exercises.

Another coverage choice is the use of anterior and posterior flaps. This option may be indicated in shorter stumps or in situations where disease precludes use of a larger posterior flap. The flap length is equal to half the diameter of the leg at the level of transection. The muscles are appropriately debulked, and the fascia is sutured together for closure. When this technique is used for proximal amputations, the fibula and peroneal nerve should be excised to prevent neuroma from becoming symptomatic with gait. 

In the face of extensive posterior flaps, the treatment of these conditions requires an interdisciplinary team approach to obtain acceptable results. Lower-limb amputation is a treatment option to attain maximal functional recovery for patients with diabetes mellitus with infections that have failed more conservative measures.

To obtain the best results after an amputation, a meticulous approach to the preoperative assessment and surgical technique is necessary. Regardless of the level, a thorough understanding of the anatomy is required to allow for good functional results and minimize postoperative complications. If these principles are routinely applied, the patient and treatment team can view an amputation as the first step in a successful rehabilitation process.

**Postoperative Considerations**

Many of the factors that affect patient outcomes after amputations have been previously described. Peters et al studied the functional level of patients who underwent diabetes-related lower-limb amputations and found that patients with toe or midfoot amputations had similar functional scores as patients with diabetes mellitus who had not undergone amputations. However, function was relatively limited in patients who underwent transtibial amputations compared with the control group. The amputations also had a detrimental effect on the patients’ psychosocial condition. Therefore, it is important for the treatment team to keep the patient’s emotional well-being in mind, regardless of amputation level. Besides a primary care physician, a surgeon, a physical therapist, and a prosthetist, it may be appropriate for a mental health professional to be involved as well.

Foot infections in patients with diabetes mellitus can be a source of significant morbidity. Many factors are involved in their development and progression, some of which are preventable with good glycemic control and frequent surveillance. The treatment of these conditions requires an interdisciplinary team approach to obtain acceptable results. Lower-limb amputation is a treatment option to attain maximal functional recovery for patients with diabetes mellitus with infections that have failed more conservative measures.

To obtain the best results after an amputation, a meticulous approach to the preoperative assessment and surgical technique is necessary. Regardless of the level, a thorough understanding of the anatomy is required to allow for good functional results and minimize postoperative complications. If these principles are routinely applied, the patient and treatment team can view an amputation as the first step in a successful rehabilitation process.

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