Amputations of the foot and ankle have been described for many centuries. In the United States, the most common reasons for foot and ankle amputation include complications of diabetes and vascular disease; more than 60% of nontraumatic lower limb amputations are in patients with diabetes. More than 6% of patients older than 60 years have symptoms of peripheral artery disease. Furthermore, the incidence of lower limb amputation is five to ten times greater than those patients without diabetes. Other reasons for amputation of the foot and ankle include severe trauma, chronic pain, infection, congenital abnormality, and malignancy.

The purpose of amputation can be defined in terms of restoring the function of a nonfunctioning or nonviable limb. Amputation should be considered the first step in a patient’s rehabilitation, rather than a failure of treatment. The goals of every amputation are to obtain wound healing, avoid infection, and return a patient to his or her preamputation ambulatory level. Additional goals include adequate balancing of the remaining muscles to avoid contracture formation and retain residual limb control. Amputations of the foot and ankle range from simple phalangeal amputation to midfoot or hindfoot amputation, ankle disarticulation, and transtibial amputation. Amputation of the midfoot and hindfoot can preserve ambulation and thereby decrease patient morbidity.

Preoperative Management

Many patients in need of an amputation have multiple medical comorbidities, such as diabetes and vascular disease. The preoperative evaluation is extremely important to a good outcome. The extremity should be evaluated for color, temperature, pulses, sensation, and tissue quality. Any contributing factor such as malunion or equinus contracture should be detected preoperatively, if possible. Radiographs and advanced imaging studies should be ordered to evaluate the bony structure and determine the extent of any underlying osteomyelitis. The evaluation should include the patient’s functional ability, social environment, nutritional and immune status, and mental state. A thorough preoperative evaluation including laboratory and vascular studies helps determine the patient’s potential for wound healing. The predictors of wound healing include serum albumin level, total lymphocyte count, transcutaneous oxygen pressure, and ankle-brachial index (Table 1).

A well-organized multidisciplinary team must care for a patient undergoing an amputation. The medical
specialists include an orthopaedic surgeon, a vascular surgeon, a medical doctor, physical therapists, a social worker, a psychiatrist, and a mental health professional. The patient should feel a rapport with the medical specialists. A psychiatric evaluation is important before surgery because an amputation is a life-changing event.9 The surgeon must be well versed in surgical technique, postoperative treatment, prosthetics, and footwear modification.

### Indications for Amputation

#### Vascular Disease and Diabetes

The indications for an amputation may be multiple and multifactorial. The combination of peripheral vascular disease and diabetes results in dysvascularity, and severe infection of the foot and ankle with sepsis may ensue. Patients at high risk of dysvascularity represent an important target group for systematic efforts to reduce the number of foot and ankle amputations.10 The most prominent subgroup is composed of patients who are African American, have diabetes, and live in a region with inadequate vascular care. In the population age 45 years or older, the incidence of vascular lower extremity amputation at or proximal to the transmetatarsal level is eight times higher in people who have diabetes than in those who do not have diabetes. One in four patients who undergo amputation may require a contralateral amputation and/or re-amputation at a higher level.11 During the past decade, the use of lower extremity amputation declined markedly in the Medicare population, and there was an increase in the nonsurgical care of diabetic ulcers.12-14 However, patients with diabetes in the Medicare population had an increasing incidence of amputation at a distal, limb-conserving location.14 Patients with poorly controlled diabetes were more likely than other patients with diabetes to undergo amputation rather than limb-salvage techniques.15,16 Limb salvage was found to represent a greater cost burden than amputation in patients with diabetes who were diagnosed with severe Charcot foot deformity.17

#### Trauma

Approximately 16% of amputations in the United States are necessitated by a traumatic etiology. Traditional injury severity scores do not predict the need for amputation after trauma.18 Despite the relatively low proportion of amputations performed after trauma, individuals with a traumatic amputation account for almost 45% of the estimated 1.6 million living people with an amputation.5 Patients who undergo a traumatic amputation frequently have complications as well as chronic pain and a relatively low likelihood of returning to work.19,20 Wartime blast injuries have resulted in a focus on amputation-related care after military trauma. US service personnel increasingly have sustained complex blast injuries that affect limb tissue availability and limit reconstruction efforts.21,22 Patients undergoing amputation after combat trauma were found to have better function and fewer psychologic symptoms than those undergoing limb salvage surgery.23,24 Regardless of treatment, however, high levels of morbidity are associated with the effects of combat warfare.25

#### Malignancy

Amputation once was the treatment of choice for a malignant bone tumor, but reconstruction is used increasingly as a result of advances in radiography, pharmacology, and surgery.26 If amputation is needed, the primary consideration is to fully excise the malignancy while diminishing the risk of local recurrence and increasing the likelihood of patient survival.26

### Level of Amputation

The functional goal of an amputation is to maintain the greatest possible residual limb length for the purpose of allowing maximal function to be restored.27 The patient’s mobility and functional independence should be maintained to the greatest extent possible. Because the level of amputation will affect the amount of energy the patient must expend, maintaining maximal limb length is important.27,28 The overall length of the residual limb is affected by the preoperative condition of the limb, the associated pathology, and general intraoperative findings. Coverage of residual osseous structures is important to prevent tissue breakdown; therefore, it is important to maintain thick myocutaneous flap coverage. After blast trauma, the level of amputation is greatly affected by the amount of residual tissue available for wound closure.29

An amputation can be performed through a joint (a disarticulation) or through bone (a transtibial amputation). A disarticulation is end bearing; loads are directly transmitted through the joint surface and metaphyseal bone. Compared with a disarticulation, a transtibial amputation has a smaller residual cross-sectional area, through which the weight is transferred indirectly. After a transtibial amputation, load transfer is through the entire limb from a total-contact prosthesis.30

Depending on the level of amputation, the energy required for ambulation differs dramatically. Children who have undergone a Syme, transtibial, or bilateral transtibial amputation do not have an increased energy cost of walking, however, and are able to walk at speeds similar to those of their peers.31
Types of Amputations

Toe Amputation

Great Toe Amputation
Great toe amputation may be indicated for pathology of the distal aspect of the hallux or a chronic condition of the nail plate. The benefits of this amputation over a disarticulation of the metatarsophalangeal joint include maintenance of the plantar flexion mechanism of the first ray and some preservation of the weight-bearing function of the hallux, which decreases the transfer stress of the adjacent rays. It is important to preserve at least 1 cm of the proximal phalangeal base during a great toe amputation.32

Metatarsophalangeal Disarticulation
If the entire great toe is affected by poor vascularity or infection, metatarsophalangeal disarticulation may be indicated to resect the entire phalanx. Several technical aspects of metatarsophalangeal joint disarticulation are important. Adequate viable soft-tissue flaps must be maintained and be capable of being closed without tension. The patient must be monitored for wound complications after surgery. When the wound has healed, the patient should be fitted with an orthotic device that prevents undue pressure on the residual first ray.32

Lesser Toe Amputation
Amputation of a lesser toe may be necessary because of ischemia or an infection such as osteomyelitis (Figure 1). A disarticulation from the metatarsophalangeal joint or a proximal phalanx resection can be performed. Maintenance of adequate flaps is important to decrease the risk of wound complications. After amputation, the patient may have adjacent toe drift or dorsal drift of the remaining phalangeal stump.

Ray Resection
Ray resection is an amputation of a toe with its corresponding metatarsal. Indications for ray amputation are osteomyelitis of a toe/metatarsal, as occurs in many patients with a plantar foot ulcer. The resection can affect one or more border or central rays. A border ray resection is the easiest to perform, with the use of a direct medial or lateral incision for the first or fifth ray, respectively (Figure 2). Care must be taken during a border ray amputation to allow for adequate flap closure, which decreases the risk of wound complications.32 Ray resections maintain foot length, and patients have good function with the aid of a shoe filler or custom insert.

A central ray resection, affecting the second, third, or fourth ray, is less often indicated than a border ray amputation. Closing the initial central ray incision is
challenging and should be performed by using as much of the original skin flap as possible.

Multiple ray amputation may be necessary in patients who have a traumatic injury, diabetes, or vascular disease. A transmetatarsal amputation may be indicated if three rays are nonviable. A medial-side amputation can result in the development of transfer lesions and loss of balance. To promote wound healing, as much of the flap length as possible should be maintained. Postoperative shoe wear modification is important for proper balance and foot propulsion.

Transmetatarsal Amputation
Transmetatarsal amputation is indicated if the patient has a severe infection, traumatic injury, deformity, or vascular disease in the forefoot (Figure 3). A transmetatarsal amputation may be of any length, but shoe wear is better accommodated with a relatively long residual limb. A short residual limb may heal more successfully, however. The advantages of a transmetatarsal amputation are that it is less technically demanding than other hindfoot amputations, and it preserves ambulation. A transmetatarsal amputation preserves the attachment of the ankle dorsiflexors and plantar flexors. Most patients can wear regular shoes with the addition of a custom insert to fill the shoe. Wound complications and ulcerations can occur after a transmetatarsal amputation because of recurrent equinus contractures, which can be corrected by a gastrocnemius or Achilles tendon release.

Midfoot Amputation
Lisfranc Amputation
The Lisfranc amputation, named after a surgeon in the French army of Napoleon, is a disarticulation of the tarso-metatarsal joint. After a Lisfranc amputation, the pull of the gastrocnemius-soleus complex and the tibialis posterior may result in an equinus contracture. Therefore, it is important to restore muscle balance by maintaining the attachment of the tibialis anterior and the peroneus brevis.

Chopart Amputation
The Chopart amputation, named after a French surgeon of the late 1700s, involves a disarticulation of the talonavicular and calcaneocuboid joints. In comparison with other hindfoot and transtibial amputations, the Chopart amputation has several benefits, the most important of which is that it retains the heel pad tissues to allow weight bearing through the amputated residual limb. The patient can be fitted for an ankle-foot orthosis rather than a below-knee prosthesis. In addition, the technique is less technically demanding than that of other amputations. The limitations of the Chopart amputation include the risk of equinus contractures and residual limb ulceration.

It is important that the ankle dorsiflexors and plantar flexors be repositioned and that the Achilles tendon be released.

Hindfoot Amputation
Pirogoff Amputation
In the Pirogoff amputation, as originally described in Russia, the forefoot, midfoot, talus, distal part of the calcaneus, and distal tibial articular cartilage are removed. The plantar skin flap is left attached to the calcaneus, which is rotated 90° dorsally to create a sensate weight-bearing surface with minimal loss of leg length (usually less than 5 cm). Because of the risk of wound failure, infection, or nonunion of the tibiocalcaneal arthrodesis, the Pirogoff amputation is rarely used for limb salvage. The use of the Ilizarov external frame has resulted in a better rate of fusion while allowing immediate weight bearing.

Boyd Amputation
In a Boyd amputation, the forefoot, midfoot, and a portion of the hindfoot are removed, with maintenance of the calcaneus. The talus is removed, and the calcaneus is shaped to articulate with the ankle mortise. The articular surfaces of the tibial plafond, malleoli, and calcaneus are débrided to achieve a fusion of the calcaneus to the tibial plafond. Achieving a successful fusion is the most difficult challenge of this amputation.

Syme Amputation
The Syme amputation is a disarticulation of the ankle joint, in which the calcaneus and talus are removed. The Syme amputation allows weight bearing by the distal tibia through the preserved heel pad and heel skin. The residual limb is longer than in a transtibial amputation, and as a result, ambulation requires a lower expenditure of energy. The complications include wound-healing difficulty,
especially in a dysvascular heel pad, and pressure ulcerations from the residual malleoli of the distal tibia.

**Transtibial Amputation**

Transtibial (below-knee) amputation is commonly performed if the foot and ankle cannot be preserved. Often this amputation is necessary in patients with diabetes who have an infected, dysvascular lower extremity. Although partial foot amputation is more durable than transtibial amputation, it may not be an option in a patient with diabetes because of osteomyelitis of the hindfoot.\(^6\) A crush or penetrating injury also can result in the need for a transtibial amputation.

As with any amputation, the surgeon must maintain the longest possible residual limb. The traditional residual limb length is 12.5 to 17.5 cm below the knee joint. In a complex injury, such as a blast injury as sustained during military combat, it may not be possible to achieve the desired residual limb length. The Ertl technique, described in 1949, is a modification of the traditional transtibial amputation designed to decrease pain and difficulty with ambulation after transtibial amputation, as caused by movement of the remaining distal tibia and fibula during direct load bearing\(^9\) (Figure 4). By increasing direct end bearing, the Ertl technique results in an improved functional outcome in young, active patients.\(^38,40\) The original bone-bridging Ertl amputation required a corticoperiosteal flap. Most subsequent modifications use a fibular strut graft with preserved muscle attachments to create the synostosis. These methods collectively are known as modified Ertl amputations or simply bone-bridging or bridging-synostosis amputations.\(^41\)

Patients who underwent a modified transtibial amputation were found to have a substantially higher rate of return to work, a lower rate of revision, and substantially higher physical and psychosocial outcome scores than patients who underwent a traditional transtibial amputation.\(^42\) Noninfectious complications were found to result in a higher rate of reoperation after the Ertl amputation than after the modified Burgess amputation, in which the posterior myocutaneous flap is transferred anteriorly, covering the residual bony limb.\(^25\) In patients with a combat injury, no evidence was found to support the belief that bone bridging contributes to a more efficient platform in the total surface-bearing socket.\(^43\)

The common complications of transtibial amputation include wound infection and neuroma formation. Heterotopic ossification, nonunion, or hardware failure also can occur after bone-bridging synostosis.\(^44\)

**Postoperative Care**

The postoperative treatment goals of amputation are to promote wound healing, decrease pain, decrease contracture, control edema and swelling, and obtain a well-fitting prosthesis. The residual limb often is wrapped in a compression dressing to decrease swelling. The incision is kept dry, and the dressing is frequently changed. On
average, sutures are kept for 2 to 3 weeks, but a longer period many be required if swelling has increased the risk of wound dehiscence.

An immediate postoperative prosthesis can be used in some patients and was found to have psychologic benefits and to lower the overall cost of treatment, the reoperation rate, and the length of hospital stay.\(^6\) Despite these advantages, immediate postoperative prostheses are not widely used in patients with a traumatic injury because of expense and time requirements, the need for adequate wound healing and early detection of infection, and the presence of associated injuries that can preclude early mobilization.\(^5\) Weight bearing is delayed until the incision is healed. After bone-bridging synostosis, full weight bearing is delayed until the bone has healed, typically at 10 to 12 weeks.

Rehabilitation begins when the wound is healed and the patient is able to bear weight. A team approach is used. The overall goal is achieve maximal function, and the specific goals commonly include functional, pain-free ambulation; a return to work; a decrease in psychosocial stress, and the elimination of pain.\(^4,6\) After combat trauma, patients with amputation were found to have a better rehabilitation outcome than those who underwent limb salvage surgery.\(^6\)

The patient’s pain may be difficult to control after amputation and can cause long-term dysfunction. The patient may have residual limb pain, back or hip pain, or phantom pain. Reduction in the intensity of acute residual limb pain appears to allow the central nervous system to lessen the memory of the pain and the likelihood of phantom pain.\(^4\) An increased level of activity also can decrease phantom pain. The tools for pain management include medications and implantable pain control devices. Pain control after a traumatic amputation is achieved through a multimodal approach.\(^4,6,9\)

### Summary

Amputation of the foot and ankle often is required to treat infection caused by ischemia in patients with diabetes and peripheral vascular disease. The treatment of patients with traumatic injury, especially combat-related injury, is particularly challenging. Patients must undergo a thorough multidisciplinary evaluation before amputation and be optimally prepared for the procedure. The surgeon must be diligent in deciding how maximal function can be obtained. The different levels of amputation require different surgical techniques, which continue to advance. After the amputation, a team approach is used to help the patient reach functional and pain control goals.

### Annotated References


Information on diabetes in the United States was summarized.


Patients treated with distal tibiofibular bone bridging did not appear to have better outcomes than patients treated with standard transtibial amputation. More information is needed before the bone-bridging technique can be recommended for standard transtibial amputation surgery. Level of evidence: III.


Foot and ankle amputation techniques were reviewed. Level of evidence: V.


A retrospective review of combat-related amputations found that reoperation was needed at a significantly higher rate overall and to treat noninfectious complications after modified Ertl bone-bridging synostosis compared with modified Burgess transtibial amputation. Level of evidence: III.


Longevity, outcome, and mortality after partial foot amputation were examined. The high ambulatory levels and the long durability of transmetatarsal and Chopart amputations suggest these amputations provide an ambulatory advantage over transtibial amputation. Level of evidence: III.


An improved understanding of the consequences of diabetic foot complications would benefit the general population and general practitioners in particular. Psychologic evaluation and support are important before and after amputation. Level of evidence: III.


The intensity of vascular care provided to patients at risk for amputation varies. Regions with the most intensive vascular care have the lowest amputation rates. Level of evidence: IV.


Comparison of the incidence of vascular lower limb amputation in patients with or without diabetes found an eightfold greater incidence at or proximal to the transmetatarsal level in patients with diabetes age 45 years or older. Level of evidence: IV.


A study of large, deep heel ulcers in 37 patients with diabetes found that 33 ulcers healed in 4 to 7 months. Transtibial amputation was performed on 4 feet. Patients with heel ulcers can be treated using a multidisciplinary approach to prevent amputation. Level of evidence: IV.


Forty-five septic feet in patients with diabetes were treated using negative pressure wound therapy between 2006 and 2008. With immediate evacuation of abscess, early vascular intervention, and appropriate débridement, this therapy is a useful adjunct to the management of limb-threatening diabetic foot infections. Level of evidence: IV.


A cost analysis found a marked decline over 10 years in the use of amputation in the Medicare population. Lower extremity amputation was more likely to be performed at distal, limb-conserving locations. Over the same period, orthopaedic treatment of ulcers increased in frequency.


Patients with a severe diabetic infection had a median hospital stay 60% longer than patients with a moderate infection, and 55% of the patients with a severe infection required an amputation compared with 42% of patients with a moderate infection. Level of evidence: IV.


Glucose control was the primary factor determining the success of a transmetatarsal amputation. The glycohemoglobin value should be less than 8 as a prerequisite for surgery. Level of evidence: III.


Preliminary data on the relative cost of transtibial amputation and prosthetic limb ﬁtting compared with limb salvage in 76 patients found that amputation was less costly than limb salvage. Level of evidence: IV.


Patients who had undergone amputation or limb salvage were retrospectively evaluated with the Mangled Extremity Severity Score for lower extremity trauma. This system was not helpful for deciding whether amputation was appropriate.


Five years after severe foot injury, most patients had painful stiffness and only 40% had returned to work. The long-term clinical and functional outcomes after treatment of a severely injured foot may be disappointing. Level of evidence: IV.


A review of 545 patients with lower extremity trauma found that patients with severe injury had a higher rate of complications, most notably infection, nonunion, wound necrosis, and osteomyelitis.

Of 63 soldiers with a blast injury to a total of 89 limbs, 32 (51%) had multisegmental injuries to the foot and ankle. Amputation of 26 legs (29%) was required. Improvised explosive devices were associated with a high amputation rate and a poor clinical outcome. Level of evidence: IV.


Limb salvage after war-related injury is complex and challenging. Innovations have been developed for complex limb reconstruction and salvage.


Analysis of two studies determined that a multidisciplinary approach and treatment environment greatly influences patient function.


A retrospective review of 324 soldiers with lower extremity trauma found that those who underwent amputation had a better functional outcome than those who underwent limb salvage. Level of evidence: III.


Functional limitations resulting from loss of muscle needed to cover bone and provide limb function are a major factor in the decision to amputate a salvaged limb.


Oxygen consumption was measured during overground walking in 73 children with an amputation at a variety of levels. Children with an amputation through the knee or distal to the knee were able to maintain a normal walking speed without substantially increasing their energy cost. Level of evidence: IV.


Factors that predict healing, functional outcome, and survival were evaluated in 62 patients with a transmetatarsal amputation. Healing was found to significantly predict subsequent ambulatory status. Level of evidence: III.


After 24 patients with infection and Charcot arthropathy underwent Pirogoff amputation with an Ilizarov external frame technique for Pirogoff amputations with ankle disarticulation and tibiocalcaneal fusion. Foot Ankle Int 2013;34(6):856-864.


Complete wound healing was documented in 7 of 15 feet in 14 patients after Boyd amputation. Revision to a more proximal amputation level was required in 7 feet. Boyd
amputation is an option for preserving limb length. Level of evidence: IV.


The rate of transtibial amputation was higher if osteomyelitis involved the heel rather than the midfoot or forefoot in patients with diabetes. Level of evidence: III.


Distal bone-bridge creation and osteomyoplasty add time and potential morbidity to a transtibial amputation procedure but are intended to lead to a more functional and physiologic residual extremity.


In a modified Ertl technique, tightrope fixation can decrease time to union through compressive forces. Level of evidence: V.


A retrospective comparison of 26 patients with transtibial amputation osteomyoplasty and 10 patients with traditional amputation after severe lower-extremity trauma found that amputation osteomyoplasty appeared to be safe and possibly was more beneficial than traditional amputation in terms of functional outcome.


No difference was found between surgical techniques with respect to bone-socket displacement. These data provided no evidence to support statements that bone bridging contributes to a more efficient platform in the total surface-bearing socket. Level of evidence: III.


Longer surgical and tourniquet times should not be considered a contraindication to using the bone-bridging amputation technique in relatively young and healthy patients. Bone-bridging and non–bone-bridging amputation techniques have comparable rates of short-term wound complications and blood loss. Level of evidence: IV.


The goal of rehabilitation of patients with severe injury is to restore limb function in the interest of reintegration into society. The US Department of Defense has developed a network of rehabilitation centers to optimize outcomes.


The US Army Pain Management Task Force evaluated pain medicine practices at 28 military and civilian institutions and provided recommendations.