Diabetes mellitus is a common risk factor for amputation. According to the Centers for Disease Control and Prevention, a diabetic ulceration is the single most common precursor to a non-traumatic amputation in the United States. Diabetes increases the risk of major amputation by twenty times. The triad of ischemia, infection, and neuropathy lead the patient on a slippery slope towards limb loss. Over half of diabetic patients with an amputation are more susceptible to develop a subsequent amputation within five years. If possible, amputation should be prevented with education, tight diabetes management, and regular foot evaluations.

In treating diabetic foot infections, the primary concern of the surgeon is to first save the patient’s life and then concentrate on salvaging as much of the foot as possible.

But what defines successful limb salvage? The ideal result is a “normal”-appearing foot with minimal morbidity. Oftentimes, the patient presents with a foot that has already failed distal procedures and a “normal”-appearing foot is already unachievable (Figure 1). A below-the-knee amputation often constitutes limb salvage “failure”. This article attempts to detail success not as a foot with five toes, but rather something between a normal-appearing foot and a below-knee amputation.

The blueprint to successful limb salvage includes identifying and addressing ischemia, identifying and treating infections, and educating the patient on prevention. Pre-operative planning is crucial. Several studies have tried to identify a single factor determining success or failure, such as hemoglobin a1c, nutritional status, lymphocyte percentage, toe pressures, renal dialysis, that are worth examining. Additionally, limb salvage must be patient-directed and realistic goals established. Once these have been decided, plans can be drawn up with what remains of the foot. A patient with sepsis stemming from the forefoot will need to sacrifice more tissue than a patient with a distal hallux ulceration. Osteomyelitis is another factor which often necessitates aggressive resection. The surgeon must also account for the biomechanical importance of tendon balancing. The primary responsibility of the surgeon is not only to treat the immediate infection but also to minimize re-ulceration, further debridement, and more proximal pedal or below-knee amputations. Wound recurrence and subsequent distal amputation site infections can approach 30%. At times, a below-knee amputation may be the only option, whether performed on initial presentation or after multiple failed salvage attempts. The goal should be to achieve a functionally plantigrade foot that is bracable and stable enough to allow the patient to remain ambulatory and avoid or minimize recurrent revisions and hospitalizations. In many cases, amputation should not be considered a failure, but a way for patients to return to normal activity.

Forefoot Amputations

Terminal or distal Symes amputation, disarticulation at the interphalangeal joints, and partial digit amputations are a common occurrence in patients with diabetes (Table 1). Fortunately, less than ten percent of lesser digital amputations re-ulcerate. However, Greteman found that 65% of hallux amputations re-ulcerate, leading to subsequent procedures (Figure 2). Lavery, et al. showed an increase in peak pressures throughout the forefoot following hallux amputations. The MPJ can be preserved by leaving the...
base of the proximal phalanx (Figure 3a, b). This helps maintain stability in the late stance phase and toe-off, thereby preventing an increase in peak plantar pressure and potential transfer lesions to the lesser metatarsals. Thus, when faced with a hallux amputation, care should be taken to preserve the FHL attachment, and leave the base of the proximal phalanx to maintain stability. Though there is a correlation between re-ulceration of the hallux and more proximal amputation of about fifty percent, current literature shows no significant correlation between hallux or lesser digital amputation and future limb loss. Nonetheless, once the patient is healed, regular monitoring and fitting with an accommodative orthosis is needed.

Partial first ray amputations are more commonly a result of distal ischemia or a failed distal amputation. This creates not only a tendon imbalance but also an alteration in the weight-bearing surface of the foot due to the loss of the first metatarsal head. A recent review on first ray procedures, not limited to amputation, but including distal amputations and metatarsophalangeal resections, showed a 20% incidence of re-amputation. It’s important to note that revisions did not occur more proximally on the medial column, but rather most commonly resulted in a lateral amputation of neighboring digits, or ultimately a transmetatarsal amputation.

Partial first ray resections have an increased risk of re-ulceration. The incidence for re-ulceration and additional surgery following loss of the first ray has prompted Wallace to state, “…TMA should be performed when the first ray has been resected previously and the patient has a non-healing ulcer under an adjacent metatarsal….”, However, a panmetatarsal head resection with ten-
doAchilles lengthening may be an acceptable alternative as well.23 In either case, it is important to accommodate the patient’s loss with orthotic devices to prevent more proximal ulcerations.

**Midfoot Amputations**

Midfoot amputations are most commonly performed in patients with severe non-reconstructible distal ischemia and gangrene, or infection, leaving minimal distal viable tissue (Table 2). The literature cites goals of these distal amputations to include removal of non-viable tissue, relief of pain, and achievement of primary healing leading to preservation of as much limb length as possible.24-27 Following debridement and demarcation, appropriate tissue flaps may need to be reconstructed for tension-free primary closure of the wound. Maximal tissue preservation is observed starting with a transmetatarsal amputation (TMA), followed by more proximal amputations at the Lisfranc joint and then the Chopart joint.

With each of these amputations, major tendinous attachments are sacrificed, thus affecting the biomechanics of the foot. As dorsiflexors of the foot are sacrificed, the plantarflexion pull of the Achilles becomes unopposed. This can result in an equinus and inversion deformity of the foot, increasing the risk for re-ulceration. However, healthy tissue may need to be sacrificed to allow tendon transfers and provide a consistent distal parabola.

The standard TMA is performed at the anatomic necks of the metatarsals with the second residual metatarsal being the longest.24 However, even with a properly performed equinovarus deformity (Figure 5a,b). Despite this, 86%-98% of patients are mobile following a transmetatarsal amputation.29, 32-33

In cases where a complete ray resection is unavoidable, or if there is insufficient tissue for closure requiring sacrificing more tissue in order to achieve a tension free closure, a Lisfranc amputation may be indicated. Aside from unopposed pull of the Achilles, this results in loss of the eversion strength of the peroneus brevis, giving the anterior tibial tendon an increased advantage. These changes result in abnormal biomechanics and increased risk of equinovarus contracture and distal lateral ulceration.

Chopart amputations are performed through the midtarsal joint (talonavicular and calcaneocuboid joints).

**TABLE 2**

<table>
<thead>
<tr>
<th>Depiction of Common Midfoot Amputations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmetatarsal (TMA)</td>
</tr>
<tr>
<td>Lisfranc’s</td>
</tr>
<tr>
<td>Chopart’s</td>
</tr>
</tbody>
</table>

**Chopart amputations are performed through the midtarsal joint (talonavicular and calcaneocuboid joints).**
ble during TMA or Lisfranc amputations as a result of infection or ischemia, a more proximal amputation may leave the patient with improved function and decrease the risk of re-ulceration, with only limited increase in energy expenditure.

**Rearfoot Amputations**

Rearfoot amputations are reserved as a last resort (Table 3). In these circumstances, the surgeon decides between a below-knee amputation and some other form of limb salvage. Some literature points to the fact that a below-knee amputation is a form of definitive closure. However, there is a 10% mortality rate and a 30% rate of conversion to an above-knee amputation.43

Additionally, though it has been observed that one-third of patients with a Symes amputation expire within five years post-procedure, one-third of patients with a below-knee amputation have a two-year life expectancy.6, 44-48 This is a true example of “form follows function.”

The functional goal of rearfoot amputations is two-fold: to provide a braceable extremity that does not re-ulcerate, and to leave a limb that the patient can transfer weight on without the use of a prosthetic. Rearfoot amputations require less than a ten percent increase in energy cost compared to a below-knee amputation which can require upwards of 40%.

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increased energy consumption.49 Among the choices of Boyd, Pirogoff, and proximal Syme amputation, the decision is often based on the surgeon’s experience. Tosun showed that greater than 50% of Boyd amputations required revisions to a more proximal level within a five-year follow-up period.50 The advantage of a Pirogoff amputation is improved preservation of limb length, with an average discrepancy of only 2.5 cm.51-54 Studies comparing rearfoot amputations have concluded that the hydraulic cushioning of the heel pad may be better preserved with a Boyd-type amputation, though it is technically more difficult than the Symes.55 Several studies have shown great success with the Syme amputation. Nearly 90% of patients healed and were ambulatory at two plus years follow-up.44-48, 57-59

**Conclusion**

Amputations in patients with diabetes are unavoidable at times and should not be considered a failure. A three-year retrospective economic

**TABLE 3**

**Depiction of Common Rearfoot Amputations**

<table>
<thead>
<tr>
<th>Amputation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyd</td>
<td>Resection through calcaneal body with removal of talus &amp; fusion of tibia to calcaneus</td>
</tr>
<tr>
<td>Pirogoff</td>
<td>Resection through calcaneal body</td>
</tr>
<tr>
<td>Syme’s</td>
<td>Resection through subtalar joint with resection of malleoli</td>
</tr>
</tbody>
</table>
analysis including both direct and indirect costs showed that a minor amputation resulted in a thirty percent lower economic cost compared to a major amputation. Success should not be defined as how much tissue is left, but rather if a stable and braceable foot that functions without ulcer recurrence or need for revision is achieved. In fact, failure can result from a surgeon trying to preserve too much tissue, resulting in subsequent ulcerations, infections, and more proximal amputations. It is not solely how much tissue is preserved, but what is done with the tissue that remains, such as preservation of the peroneal tendons, lengthening of the Achilles tendon, or transferring the extensor and tibialis anterior tendons.

The goal of limb salvage surgery is for the patient to leave the hospital with decreased risk for subsequent revision and hospitalization. Repeat surgery has significant cardiac and anesthesia risks in this patient population as well as increased costs of hospitalizations and operating room time. Because of already decreased life expectancy in these patients, the patients’ remaining days should not be spent in and out of the hospital in order to maximize their quality of life. Successful salvage should take the focus off of appearance and emphasize function. PM

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