Diabetic Foot Surgery: An Overview

Procedures have assumed an increasingly important role in patient care.

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During their lifetime, up to 30% of people with diabetes will develop a foot ulcer.[1] Diabetes-related foot ulcers and lower extremity amputations result in a major burden for patients, their family, and the healthcare system.[2] Interest in this complex and challenging specialty has been growing and, in recent decades, there has been acceptance of a shift towards operative correction of diabetic foot deformities. Surgical management of diabetic foot deformities has now become an integral part of the overall care.

There are a number of component causes that interact to complete the causal pathway to foot ulceration. In their landmark paper, Reiber and colleagues found the most frequent component causes are peripheral neuropathy, deformity, and trauma.[3] Sensory neuropathy predisposes to unfelt repetitive trauma and motor neuropathy leads to a muscle tendon imbalance and ultimately results in foot deformity. Deformity leads to increased plantar pressures and when these are combined with sensory neuropathy, ulcer formation is likely. It is prudent to consider foot deformities as a possible cause for all foot ulcers (new and recurrent). Peripheral arterial disease is present in up to 50% of patients with a diabetic foot ulcer, and a small percentage of foot ulcers are purely ischemic. Most foot ulcers are purely neuropathic or neuro-ischemic.[4]

A deformity is any foot condition which predisposes the foot to increased pressures. Common deformities in this population include hammertoes, prominent metatarsal heads (often the result of a hammertoe with resultant retrograde pressure on the metatarsal head), bunions, hallux rigidus, ankle equinus, Charcot foot, and partial foot amputations. Each of these deformities results in increased focal pressures and contribute to development of ulceration. Therefore, identifying and treating these deformities is an essential component of care.

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Off-loading is a cornerstone in the treatment of diabetic foot ulcers and is one of the most important interventions with the strongest evidence available for healing foot ulcers.[4,5] Off-loading the deformity is commonly used in clinical practice for ulcer prevention, ulcer treatment, and plantar pressure reduction.[4] Non-removable devices are favored over removable devices and the preferred offloading treatment is a total contact cast (TCC) or a removable CAM walker rendered irremovable.[4,5] However, a TTC does not correct the underlying fixed deformity and one study showed an 81 percent ulcer recurrence rate after two years.[6]

Quality of life for patients is often not improved with "successful" accommodative treatment, and there is growing interest in operative correction of the acquired deformity with the goals of achieving both the traditional goals of resolution of infection and limb salvage as well as the desire to improve quality of life.[7] In situations in which there is a deformity that prevents the efficacy of short- and long-term solutions, surgical intervention is warranted. Addressing the underlying deformity and ameliorating the resultant high pressures by structurally re-aligning or removing bony prominences is the rationale for foot surgery.[8] Surgical correction of the deformity has now become an integral part of the overall care. By eliminating the deformity, one removes a risk factor for ulceration and also reduces the risk of ulcer recurrence. There have been numerous descriptive studies detailing various surgical techniques in the treatment of diabetic foot deformities. Recent studies support the shift from accommo-

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dative treatment of the deformity to the modern interest in operative correction of deformity.[7]

A classification system was developed to stratify the type of surgery into well-defined risk groups. Each class is distinguished by the presence of neuropathy, the wound status, and its risk for subsequent amputation. This system divides non-vascular diabetic foot surgery into four classes: elective, prophylactic, curative, and emergency.[9]

Elective surgery (Class I) refers to reconstructive procedures on patients who have diabetes with intact sensation (no neuropathy). There is low morbidity associated with elective foot surgery.

Prophylactic surgery (Class II) refers to reconstructive procedures performed to reduce the risk of ulceration or re-ulceration in patients who have neuropathy and do not have an open wound. The goal of surgery in this group is to correct an underlying deformity and restore function, thereby reducing plantar pressures and lowering the risk of ulceration or recurrent ulceration.

Elective and prophylactic foot-sparing procedures have become important strategies to preserve the functional anatomy of the foot while addressing the deformity and lowering the risk of ulceration.

Curative surgery (Class III) is performed on patients with an open wound; these are procedures designed to assist in healing the wound and reduce the risk of future re-ulceration. These procedures are often performed to provide a cure by joint resection or by removing bone prominences.[8]

Emergent surgery (Class IV) is, as the name implies, an emergency surgery for limb-threatening infection, and as a result, will often lead to partial foot amputation.

Specific types of procedures are not restricted to a single class of surgery. Many procedures are used across multiple foot surgery classifications.

Elective and Prophylactic Foot Surgery

Understanding the etiology of foot deformities in patients with diabetes allows for proactive surgical management of the foot in the anticipation of the development of deformities and ulcerations. Elective and prophylactic foot-sparing procedures have become important strategies to preserve the functional anatomy of the foot while addressing the deformity and lowering the risk of ulceration.[8] Common foot deformities include hammertoes, bunions, ankle equinus and hallux rigidus.

Hallux rigidus, where the limited metatarsophalangeal joint dorsiflexion increases pressure at the distal hallux during ambulation, can lead to the formation of calluses under the hallux and subsequent ulceration. This is a clear indication for prophylactic surgery to increase motion, reducing distal pressure and lowering the risk of developing an ulceration.[10]

Charcot foot is a complex and challenging deformity and reconstruction is indicated for the deformed, unstable foot at risk for skin breakdown (prophylactic surgery) or with a non-healing wound (curative surgery).

The goal of Charcot foot surgery is to obtain a stable, plantigrade foot that remains ulcer-free. Historically, high failure rates were associated with Charcot foot reconstruction; however, over the past decades, evolving techniques have focused on increasing stability of fixation construct. Advances in fixation concepts and newer techniques, termed superconstructs, have improved outcomes. The superconstruct concept focuses on extending the fusion beyond the zone of injury, performing bone resection to correct deformity, using the strongest device that can be tolerated by the soft tissue, and applying the device in a position that maximizes mechanical function.[11,12]

Curative procedures address the deformity, and in addition, address infection and/or ulceration.

Various methods of fixation have been described and include internal fixation, external fixation, and a combination of the two. Plantar plating allows the fixation to extend past the zone of injury and by placing the plate on the tension side of the fusion, superior strength is obtained. Placement of plantar plates requires extensive dissection. Intramedullary fixation or "beaming" technique provides similar stability and, as opposed to plantar plates, can be inserted in a minimally invasive manner. Intramedullary fixation also allows for compresses across multiple fusion sites and the ability to span across the zone of injury.[12] Recently, Manchanda and colleagues found that including the subtalar joint as part of the superconstruct with intramedullary beaming for midfoot Charcot reconstruction is associated with a lower incidence of complication than does intramedullary beaming of the midfoot alone.[12]

Wukich and colleagues reported on a consecutive cohort of 245 patients with Charcot foot. Approximately 70% required reconstructive surgery and the overall limb salvage rate in the surgical group was 90%. Of note, the presence of a Charcot-related foot wound at initial

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presentation increased the likelihood of major lower extremity amputation by a factor of 6.[13]

Kroin and colleagues reported on 25 consecutive patients undergoing operative reconstruction for non-plantigrade midtarsal Charcot foot arthropathy and demonstrated that successful operative reconstruction of midtarsal Charcot foot arthropathy improved quality of life.[7]

Curative Foot Surgery

Curative procedures address the deformity, and in addition, address infection and/or ulceration. They are often performed to provide a cure by joint resection, removing bone prominences, resecting infected bone (osteomyelitis), and to reduce the risk of ulcer recurrence. Researchers have described various surgical procedures to assist in ulcer healing. These "curative"-type procedures include Keller arthroplasty, metatarsal head resection, exostectomy, Achilles tendon lengthening, and Charcot reconstruction. Renewed interest in minimally invasive surgical techniques have the potential to lower previously discouraging high complication rates.

Examples include percutaneous flexor tenotomies for tip of toe ulcers,[14] minimally invasive metatarsal osteotomies for ulcers under the metatarsal heads,[15] and a minimally invasive technique for the treatment of Charcot deformity.[16]

Emergent Foot Surgery

In the presence of infection and or osteomyelitis, surgery becomes a critical component of care. Most mild and moderate infected diabetic foot ulcers respond well to local debridement, offloading, and culture-directed antibiotics. However, some may rapidly progress to a limb-threatening infection which requires emergency surgery to control infection. A delay in treatment will result in further tissue loss and may ultimately lead to major limb loss.

Prompt recognition of infection is essential for optimal outcome. A detailed clinical exam will often reveal the signs consistent with infection. Radiographs may determine osteomyelitis and MRI and may be considered to determine the extent of infection. Once the diagnosis is established, the goal is, first and foremost, to eradicate infection. A properly performed debridement consists of exposing all infected tissue planes, exploring tendon sheaths, and removal of infected and non-viable soft tissue and bone. The extent of infection always dictates the extent of debridement.[17] Deep tissue cultures (bone and soft tissue) using clean, unused instrumentation are obtained for microbiology cultures. Culture-directed intravenous antibiotics are continued until complete eradication of infection is achieved.[8] Repeat surgical debridement may be necessary to fully control infection. When properly performed, a surgical debridement, or incision and drainage, removes devascularized tissue and necrotic material, eliminates dead space and reduces wound contamination.[17]

Debridement triumphs reconstruction every time. It is only after infection is resolved that the focus may then be shifted to the functional status of the foot.

Debridement trumps reconstruction every time. It is only after infection is resolved that the focus may then be shifted to the functional status of the foot. If peripheral artery disease (PAD) is suspected, further vascular assessment is performed and, if warranted, referral to vascular specialists is performed for further work-up and possible revascularization to restore adequate blood flow to the foot. Restoration of adequate perfusion is essential to allow the surgeon to perform indicated functional reconstructive, or minor foot-sparing amputation procedures.[18] Non-functional foot amputations will lead to further complications and are to be avoided; as such, more proximal partial foot amputations (i.e., TMA) are preferred over an unbalanced, more distal forefoot amputation. Any resultant deformity can be managed with appropriate footwear with or without a brace, or surgical reconstruction.

Conclusion

Over the past several decades, there has been increased interest in the surgical management of diabetic foot disorders and today surgery plays an integral role. In a 2019 update, the International Working Group on the Diabetic Foot (IWGDF) identified "treating risk factors for ulceration" as one of five key elements to prevent foot ulcers.[5] Operative management of a diabetic foot deformity directly addresses one of the key elements to prevent ulceration (and re-ulceration) as identified by the IWGDF. While techniques and indications continue to evolve, diabetic foot surgery has assumed an increasingly important role and is an essential component of care. **PM**

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