Management of diabetic neuropathic foot and ankle malunions and nonunions

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The management of diabetic neuropathic foot and ankle malunions and/or nonunions is often complicated by the presence of broken or loosened hardware, Charcot joints, infection, osteomyelitis, avascular bone necrosis, unstable deformities, bone loss, disuse and pathologic osteopenia, and ulcerations. The author discusses a rational approach to functional limb salvage with various surgical techniques that are aimed at achieving anatomic alignment, long-term osseous stability, and adequate soft tissue coverage. Emphasis is placed on techniques to overcome the inherent challenges that are encountered when surgically managing a diabetic nonunion and/or malunion. Particular attention is directed to the management of deep infection and Charcot neuroarthropathy in the majority of the cases presented.

Keywords: charcot foot; external fixation; malunions; nonunions; diabetic foot

Foot and ankle malunions amongst the diabetic neuropathic patient are often the result of Charcot neuroarthropathy following an initial traumatic event, delayed healing with failure of hardware, early weight bearing, and/or patient non-compliance. Patients with peripheral neuropathy often are unable to self-protect when a weight bearing status is initiated resulting in pathologic forces across fractures and/or previously dislocated joints prior to osseous healing, which is typically delayed in this patient population. In addition, these traumatic forces can initiate a cascade of events that results in an acute Charcot neuroarthropathy that can lead to further fractures, dislocations, and unwarranted deformities. Often, primary arthrodesis of the affected joint(s) is required as opposed to osteotomy correction and realignment procedures that are typically performed in the non-diabetic patient with a sensate extremity. Certain clinical scenarios are amenable to either revisional fracture management and/or corrective osteotomies; however, super-constructs with an understanding of the pathologic forces as well as an appreciation for the soft tissue envelope and the vascularity of the extremity are paramount amongst these cases (1–11).

A nonunion of the foot and ankle in the diabetic neuropathic patient can be very challenging to treat. Bone loss and paucity of bone quality are often problems in nonunion revisional surgery, especially in the presence of deep infection or in patients who have Charcot fractures and dislocations. The surgeon should always try to determine the possible causative factor that led to a nonunion during the primary surgery to avoid further surgical failure and to minimize potential future complications. Osteomyelitis causing an infected nonunion should be considered in the presence of open wounds, sinus tracts, history of open wounds, and/or previous infections. In addition, the late bone erosion and collapse often encountered in latent-chronic infections can be very difficult to decipher amongst Charcot joints and often becomes a diagnostic dilemma. The author prefers in these case scenarios to rely on intra-operative bone biopsy and culture results to determine if infection is present and to guide further treatment. This is typically more conclusive and less expensive than utilizing multiple imaging modalities and nuclear medicine studies that often necessitate eventual bone biopsy and cultures for definitive diagnosis.

Infection in the diabetic neuropathic patient with a nonunion poses great challenges. Some surgeons elect to retain internal fixation provided it is stable and perform further osseous debridements and staged reconstructive efforts while managing the infection with systemic antibiotics based on intra-operative cultures. The author prefers to remove all internal fixation and to debride and excise all infected and/or non-viable bone and soft tissue.

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regardless of the defect. The presence of biofilm cannot entirely be eradicated until the hardware is removed and the bone adequately debrided. Each screw hole should be thoroughly debrided along with the surface of the bone in which internal fixation plates were placed. Infected intramedullary rods should be treated with removal, sequential reaming of the medullary canal, thorough curettage, and lavage of the entire medullary canal. Multiple cultures, usually three, of the bone should be obtained to determine the pathogenic organisms. Infected osseous defects are best managed with antibiotic impregnated cement spacers, antibiotic impregnated beads, and/or antibiotic impregnated cement medullary rods that manage the dead space and provide osseous stability while simultaneously eluting a local concentration of antibiotic to the infected area. This is often performed to eradicate deep infection so further staged reconstructive procedures can be performed.

External fixation is a valuable tool for the management of these complex cases. The utilization of external fixation allows the surgeon the ability to provide osseous stabilization and correct deformities by both static and dynamic means to achieve bone healing. In addition, external fixation has many advantages over internal fixation where preservation of the soft tissue envelope and vascularity is needed. In most of these clinical scenarios the soft tissue envelope is poor and the utilization of internal fixation can pose a threat to wound healing and ultimately bone healing. The main advantage and necessary utilization of external fixation is for revisional surgery compromised by underlying foot and ankle infections. External fixators are not only employed to achieve osseous stabilization and to promote bone healing but are useful for effectively off-loading the soft tissues while allowing easy access for wound assessments and further wound care as needed. In certain scenarios stable fixed internal fixation constructs are required and necessary to achieve osseous stability if the soft tissues permit. In most cases the external fixation construct if assembled and applied appropriately will be stable and bone fixation should be stable. In certain case scenarios involving the diabetic neuropathic patient this cannot be achieved with external or internal fixation alone and a combination of the two is required if the soft tissues permit (1–5).

Soft tissue management in these cases cannot be overlooked and must be addressed. Soft tissues that are avascular inherently provide minimal vascularity to the osseous segments that impedes bone healing. In certain clinical scenarios the utilization of muscle, rotational, pedicle, and free flaps not only provide durable soft tissue coverage but serve as an adjunct in promoting bone healing.

Case presentations

Case 1
A 70-year-old female with a past medical history significant for diabetes mellitus, peripheral neuropathy, Charcot neuroarthropathy, hypertension, hypercholesteremia, and renal insufficiency initially presented with an unstable Charcot joint about the rearfoot and ankle with two draining sinus tracts from the medial aspect of the ankle joint. The patient reported eight previous surgical attempts at the affected extremity. Two procedures approximately 8 months apart over 2 years ago were performed to achieve an ankle arthrodesis with external fixation that ultimately resulted in an infected nonunion and Charcot neuroarthropathy of the midfoot and rearfoot (Fig. 1A and B). A total of six procedures were then performed for infection that consisted of incision and drainage procedures with collection of bone and soft tissue cultures to guide systemic antibiotic therapy with no further attempts at reconstruction of the deformity. Multiple organisms were present from numerous cultures over the last 3 years. Recommendation was for below knee amputation prior to referral. The patient was initially treated with surgical excision and

![Fig. 1. Anterioposterior view of an infected nonunion of the ankle with Charcot neuroarthropathy (A). Lateral view demonstrating severe deformity about the ankle, rearfoot, and midfoot (B).](image-url)
debridement of all non-viable and infected soft tissue and bone that resulted in a talectomy, distal tibia resection, and wide resection of the tarsal bones. Deep intra-operative soft tissue and bone cultures were obtained to determine the pathogenic organism(s) to guide further antibiotic therapy. A hybrid external fixation device was initially applied to provide osseous stability and to off-load the soft tissues. The patient returned to the operating room 7 days from the initial debridement for a second osseous debridement, thorough lavage of the wound, and placement of antibiotic beads with wound closure to treat the dead space and deep infection (Fig. 2A and B). The wounds healed at 4 weeks and revisional surgery was performed 6 weeks after the second surgical debridement. During this period, parenteral antibiotic therapy was maintained and the patient was kept non-weight bearing in the hybrid external fixator. Revisional surgery consisted of a tibio-calcaneal fusion with autogenous bone grafting harvested from the proximal tibia. Osseous stabilization for the tibio-calcaneal fusion was achieved with a multiplane circular external fixator (Fig. 3A and B). This was advantageous given the history of infection while providing the necessary stabilization required given the bone loss present from the previous debridement. The patient was maintained in the external fixation device for 110 days and was then immobilized in a non-weight bearing cast for 6 weeks, a weight bearing cast for another 4 weeks, then transitioned to a custom shoe with a double upright brace that she wears currently at 30 months post-operatively (Fig. 4A and B).

Fig. 2. Intra-operative fluoroscopy demonstrating extensive tarsal bone resection, placement of antibiotic impregnated beads, and application of hybrid external fixator (A). Lateral view demonstrating talectomy, distal tibia resection, and placement of antibiotic impregnated beads (B).

Fig. 3. Anterioposterior view with application of a multiplane circular external fixator for revisional tibio-calcaneal fusion (A). Lateral view demonstrating good alignment of the foot to the tibia despite the extensive bone loss (B).
Case 2
A 63-year-old female initially presented with a past medical history of diabetes mellitus, peripheral neuropathy, Charcot neuroarthropathy, coronary artery disease, lymphedema, hypertension, and rheumatoid arthritis. She underwent an attempted tibio-talo-calcaneal fusion with external fixation for management of a Charcot joint about the rearfoot and ankle. She did not report a previous infection with the initial surgery. As she tried to progress her weight bearing status 3 months after the initial surgery, varus deformity about the rearfoot and ankle developed within a period of 2-3 weeks. On initial presentation she was unable to weight bear but could stand on the affected extremity. She displayed significant edema to the extremity secondary to lymphedema but no open wounds were present or clinical signs of infection. Initial radiographs revealed resorption of the talus with nonunion of the ankle and subtalar joint with severe varus deformity noted to the heel that was rigid (Fig. 5A, B, and C). The first stage of surgical management of this condition consisted of obtaining a bone biopsy and three bone cultures. The pathology report documented chronic osteomyelitis. All three bone cultures revealed Staphylococcus epidermidis. At this time the patient was placed on parenteral antibiotic therapy. A second staged procedure was performed 10 days after the initial bone biopsy and additional cultures were taken. A talectomy at this time was performed with placement of an antibiotic impregnated spacer and closure of the wounds with application of a well-padded splint (Fig. 6). The patient then returned to the operating room 6 weeks later for removal of the antibiotic spacer and repeat bone cultures. The cultures were negative for bacterial growth and the patient returned to the operating room 7 days later for a revisional tibio-calcaneal fusion with a blade plate and application of a multiplane external fixator (Fig. 7A and B). The external fixator was removed 12 weeks later and the patient was placed into a non-weight bearing cast for 4 weeks with the application of an external bone stimulator and then progressed into a walking cast for another 4 weeks. The patient then resumed full ambulation with a custom high-top shoe and double upright brace. She has no further progression of deformity and has maintained an ambulatory status for the last 6 months, despite the absence of complete trabeculation across the arthrodesis site (Fig. 8A and B). Closer observation is warranted in this case scenario.

Case 3
A 74-year-old female presented with a past medical history significant for diabetes mellitus, peripheral neuropathy, coronary artery disease with previous coronary artery bypass 3 years ago, peripheral arterial disease with right lower extremity bypass 1 year ago, renal insufficiency, aortic stenosis, chronic obstructive pulmonary disease, depression, and bipolar disorder. The patient was initially managed at another institution for a trimalleolar ankle fracture/dislocation. A closed reduction with cast application was performed and the patient was instructed to follow-up in the office within 1 week. The patient was non-compliant and the next evaluation was not until 6 weeks later for removal of the antibiotic spacer and repeat bone cultures. The cultures were negative for bacterial growth and the patient returned to the operating room 7 days later for a revisional tibio-calcaneal fusion with a blade plate and application of a multiplane external fixator (Fig. 7A and B). The external fixator was removed 12 weeks later and the patient was placed into a non-weight bearing cast for 4 weeks with the application of an external bone stimulator and then progressed into a walking cast for another 4 weeks. The patient then resumed full ambulation with a custom high-top shoe and double upright brace. She has no further progression of deformity and has maintained an ambulatory status for the last 6 months, despite the absence of complete trabeculation across the arthrodesis site (Fig. 8A and B). Closer observation is warranted in this case scenario.

Fig. 4. Anterioposterior view demonstrating good alignment of the tibio-calcaneal fusion (A). Lateral view demonstrating successful management of the bone loss and trabeculation of the tibio-calcaneal fusion (B).
weeks from the initial injury. The treating physician repeated radiographs that revealed a chronically dislocated ankle joint and referred the patient for surgical intervention (Fig. 9A and B). Upon initial evaluation, the patient had a patent bypass graft and the foot was well-perfused. The distal tibia was tenting the skin anteriorly with no evidence of ulceration, wound necrosis, or signs of infection. The deformity was not amenable to close reduction and was rigid. Surgical management for this condition consisted of a primary ankle arthrodesis through an anterior approach with application of an anterior plate (Fig. 10A and B). The rationale for the anterior plate was to prevent the pathologic force of the tibia displacing anteriorly. The patient was kept non-weight bearing for 3 months and then progressive weight bearing was advanced with a walking boot over the next 4 weeks. The patient resumed an ambulatory status at 4.5 months post-operatively and was last evaluated 6 months post-operatively revealing no short-term complications. Long-term outcome is still to be determined for this case.

**Conclusion**

The surgical management of malunions and nonunions of the diabetic neuropathic lower extremity poses a great challenge to the treating surgeon. The complexity arises especially amongst patients who previously demonstrated non-compliant behavior that, through the author’s experience, seems to be more evident in this patient population. For this reason, patient education with
involvement of family members along with coordination of the patient’s care among the team of medical and surgical specialists who have an interest in diabetic limb salvage is paramount. In addition, these cases are best managed by a surgical team with experience in this field as complications are often present, and successful treat-

Fig. 7. Anterioposterior view demonstrating good alignment of a revisional tibio-calcaneal fusion performed with a blade plate and application of a multiplane circular external fixator (A). Lateral radiograph demonstrating good alignment of the tibio-calcaneal fusion (B).

Fig. 8. Anterioposterior standing radiograph taken 6 months after the patient resumed an ambulatory status with a custom shoe and double upright brace (A). Lateral radiograph taken at the same time demonstrating good alignment and no hardware failure despite the absence of complete trabeculation across the arthrodesis site. Close observation and bracing is required for this case scenario (B).
Fig. 9. Anterioposterior radiograph demonstrating a severely comminuted neglected trimalleolar ankle fracture and dislocation 6 weeks from the initial injury (A). Lateral radiographs demonstrate the pathologic force of the tibia displacing anteriorly causing potential soft tissue compromise to the anterior ankle (B).

Fig. 10. Anterioposterior radiograph demonstrating a primary ankle fusion that was performed through an anterior approach (A). Lateral radiograph demonstrates good alignment and prevention of the pathologic force of the tibia displacing anteriorly through application of an anterior plate (B).
ment usually manifests only when these complications are appropriately managed.

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