The Neuropathic (Charcot) Ankle

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There is a growing consensus on both surgical indications and clinical outcome expectations for the treatment of diabetes-associated neuropathic (Charcot Foot) arthropathy at the midfoot level [1–5]. The historical metrics for measuring successful clinical outcomes were simply resolution of infection and limb salvage. There was no reported metric associated with brace use or ambulatory activity. It is currently appreciated that successful treatment is associated with the ability to walk using commercially-available therapeutic footwear and avoid the need for cumbersome orthotic devices [6–8]. These goals are generally achieved by correcting the acquired deformity and achieving a stable plantigrade foot. Treatment guidelines are not as well understood, nor are outcome expectations as favorable, when the ankle joint is involved [9]. The goals of this chapter are to explain the impediments to achieving favorable clinical outcomes in the treatment of Charcot Foot arthropathy when the ankle joint is involved in the neuropathic process, and describe the current strategies for achieving a stable plantigrade foot capable of walking with commercially-available therapeutic footwear.

1 Why Is the Ankle Different

The human foot is a unique organ that is adapted for weight bearing on both level and nonlevel surfaces. It is composed of approximately 28 to 32 bones that pre-position the very durable plantar tissue to accept the forces associated with weight bearing. The individuals most prone to develop Charcot Foot Arthropathy are long-standing morbidly obese diabetics with peripheral neuropathy. In order to fully comprehend the pathophysiology associated with this disorder, one must appreciate that during the period of development of peripheral neuropathy, affected individuals also develop osteoporosis [1]. Eichenholtz Stage I Charcot Foot Arthropathy actually behaves similar to a “stress fracture” associated with either a single episode of trauma, or repetitive loading of biomechanically poor quality bone. Most patients heal after a period of immobilization and do not progress to either the “nonunion,” or malunion deformity associated with Eichenholtz Stage III disease. The best observational study associated with Charcot Foot Arthropathy would suggest that

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the incidence is actually approximately 0.3 per 1000 per year [10]. The initial presentation of Charcot Foot is often wrongly diagnosed as gout, cellulitis, tendonitis, or other maladies, with the actual diagnosis of Charcot Foot not being appreciated until much later when x-rays are taken for various reasons [11]. If the "stress fracture" does not progress to union, the deformity will likely progress [12, 13]. If the deformity progresses to the point where the foot is not clinically or radiographically plantigrade, tissue breakdown with subsequent infection is likely [14, 15].

The difference in biomechanical loading of the ankle joint is likely responsible for the increased potential for a poor clinical outcome when the ankle joint is involved in the neuropathic process. The foot is normally loaded in a plantigrade fashion, whereas the ankle is loaded in valgus (Fig. 1). If an ankle fracture does not progress to union, the weight bearing vector will displace laterally, accentuating valgus loading, thus increasing the deforming forces [12, 13] (Fig. 2). This explains the observation that, while the development of Charcot Foot Arthropathy at the midfoot level be attritional, the neuropathic (Charcot) ankle almost always develops following a fracture [9].

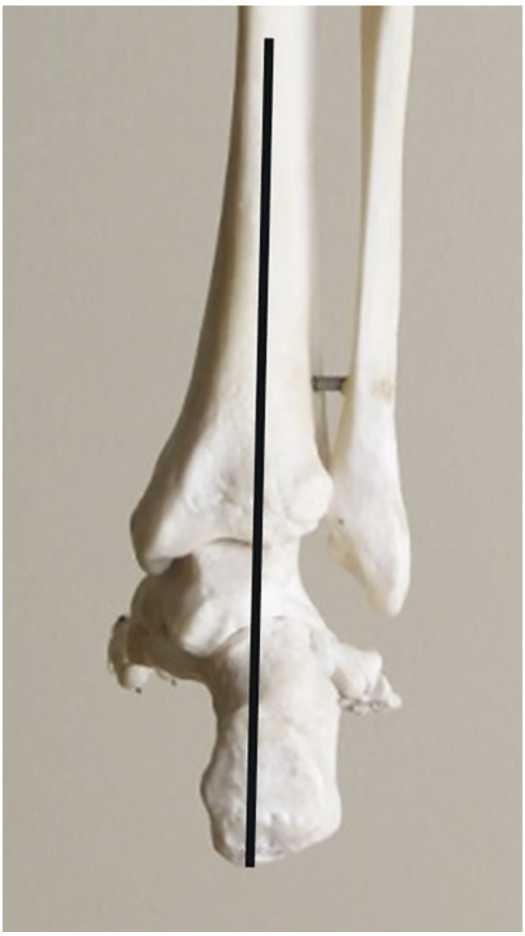

Fig. 1 The normal weight bearing line passes through the middle of the ankle, with a vector that interacts with the floor through the heel

Fig. 2 An unstable ankle fracture with widening of the ankle displaces the weight-bearing vector laterally. The biomechanical loading applied to the unstable ankle tends to accentuate the deforming forces

2 Treatment of Unstable Ankle Fractures in Neuropathic Diabetics

Connally first observed the risk for amputation in diabetics following an ankle fracture [16]. Multiple subsequent authors have demonstrated the high risk for the development of complications following ankle fracture in diabetics with peripheral neuropathy [13, 17–23]. The logical explanation for the increased rate of complications in diabetics is the associated comorbidities of osteoporosis and immunodeficiency. The common development of mechanical failure following internal fixation of ankle fractures in diabetics is likely associated with the inability of standard orthopaedic implants to maintain mechanical construct stability in severely poor quality bone. The increased rate of postoperative infection is, likewise associated, with the known impaired immunity in this patient population [2]. This combination of factors influenced Johnson to advise "doubling down" on diabetic ankle fractures by *doubling* the magnitude of surgical fixation and *doubling* the period of immobilization [19–21, 24, 25].

The first step in decision-making in diabetic patients with an ankle fracture is the decision of which ankle fractures require surgery. The insensate diabetic patient in Fig. 3 has what appears to be a stable ankle fracture. This was confirmed with a weight-bearing radiograph taken 1 week later, demonstrating no loss of alignment. The decision was made to continue nonoperative treatment. Radiographs at both 6 and 12 weeks demonstrated delayed healing without loss of alignment. Nonoperative treatment was continued. Radiographs taken at 6 months following injury demonstrate eventual radiographic union (Fig. 3). A similar diabetic patient with peripheral neuropathy presented with the radiographs demonstrated in Fig. 4. A weight-bearing radiograph at 1 week demonstrated instability, leading to treatment with augmented internal fixation. *Augmented* internal fixation can be accomplished via a large transarticular pin crossing the ankle joint, or multiple syndesmotic screws, using the fibular plate as a "washer" for the screws (Fig. 5) [19–21].

The use of closed reduction and stabilization with a percutaneous retrograde locked intramedullary nail without arthrodesis has recently been advocated for complex ankle fractures in high risk patients or patients with a questionable soft tissue envelope (Fig. 6) [26].

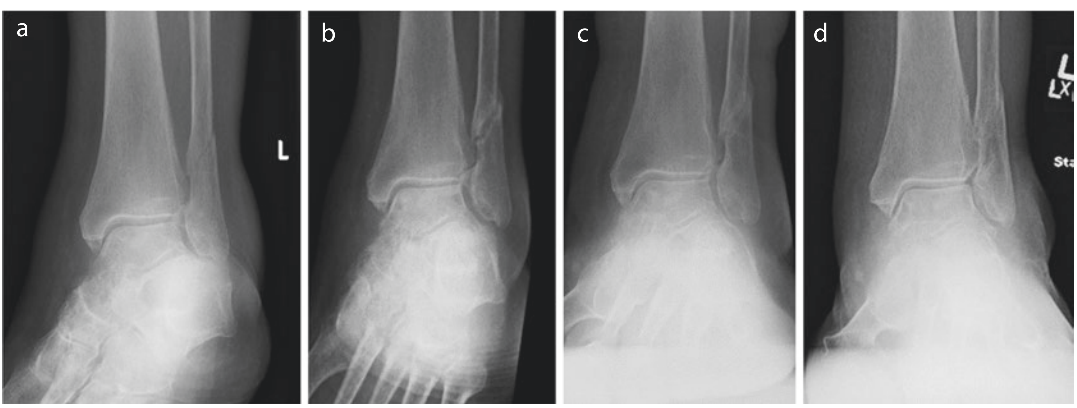

Fig. 3 This diabetic patient with peripheral neuropathy presented to the Emergency Room with ankle pain following a twisting injury (**a**). She was treated with a fracture boot and still had discomfort at 6 weeks following injury (**b**). A 12-week radiograph did not demonstrate bony union in spite of her not being symptomatic (**c**). Radiographs at 6 months demonstrate bony union (**d**). (Used with permission of Jeremy McCormack)

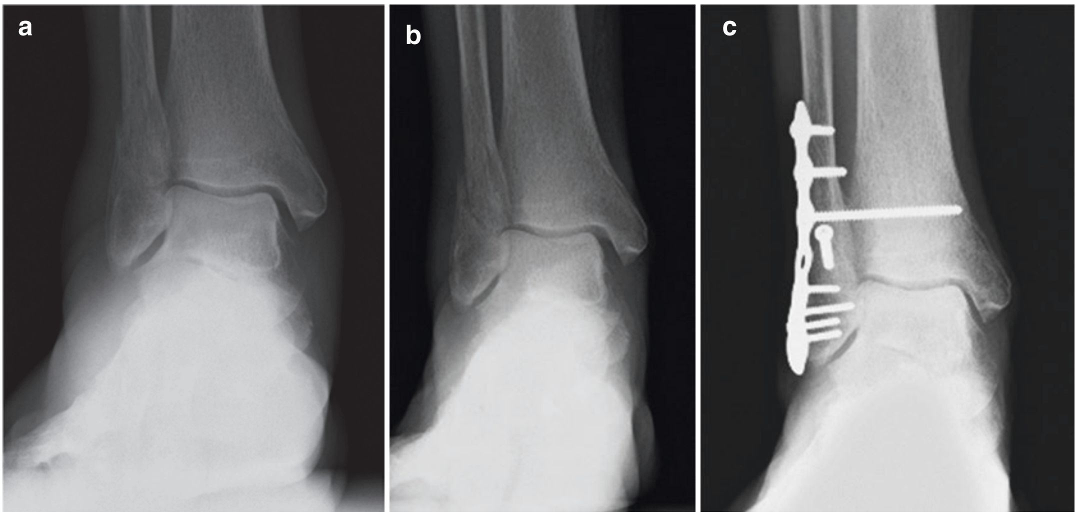

Fig. 4 Emergency Room radiographs of a similar patient with ankle pain following an injury (**a**). Weight-bearing radiograph at 1 week demonstrating unstable ankle fracture (**b**). Radiograph following successful open reduction internal fixation (**c**). (Used with permission of Jeremy McCormack)

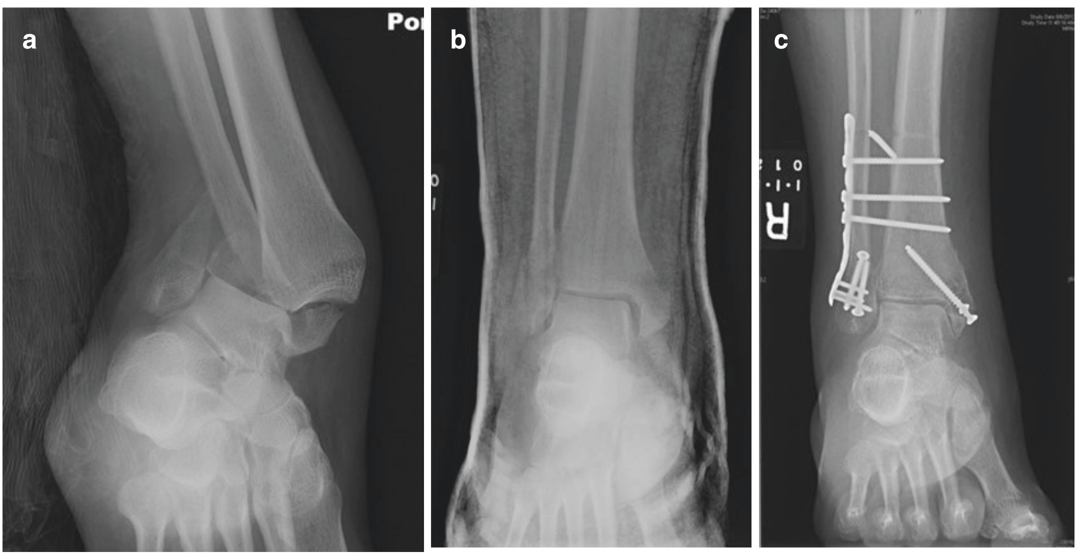

Fig. 5 Unstable ankle fracture following a low energy injury in an insensate diabetic patient (**a**). Radiographs following closed reduction reveal the low energy nature of the injury (**b**). Radiographs following open reduction internal fixation with augmented internal fixation (**c**). The lateral plate is used as a *washer* for the syndesmotic screws that are used for augmented internal fixation

Fig. 6 This 72-year old neuropathic male sustained this unstable distal tibia fracture (**a**, **b**). He was initially treated with closed reduction and application of a damage control external fixator. This was followed by open reduction with standard orthopaedic implants (**c**). The patient was strictly non-weight bearing, but had this radiograph 2 weeks later (**d**). The failed implants were removed, and an external fixator was placed until the articular component of the fracture healed (**e**). A percutaneous locked nail and bone grafting led to eventual painless union at 2 years (**f**, **g**, **h**)

3 Arthrodesis in the Neuropathic Patient with No Infection

Neuropathic arthropathy can develop in a diabetic patient with long standing peripheral neuropathy following fracture or recurrent ankle sprains. Ankle replacement is generally not advised in diabetics with peripheral neuropathy due to the high risk for failure. Plate and screw constructs to achieve ankle or tibiotalocalcaneal arthrodesis is probably best avoided due to the potential for mechanical failure in patients with known osteoporosis and poor bone quality. The most reliable mechanical construct for achieving tibiotalocalcaneal arthrodesis is a retrograde locked intramedullary nail [9, 27]. Augmentation with one or two transarticular large fragment screws increases the likelihood of achieving a successful arthrodesis (Fig. 7) [28].

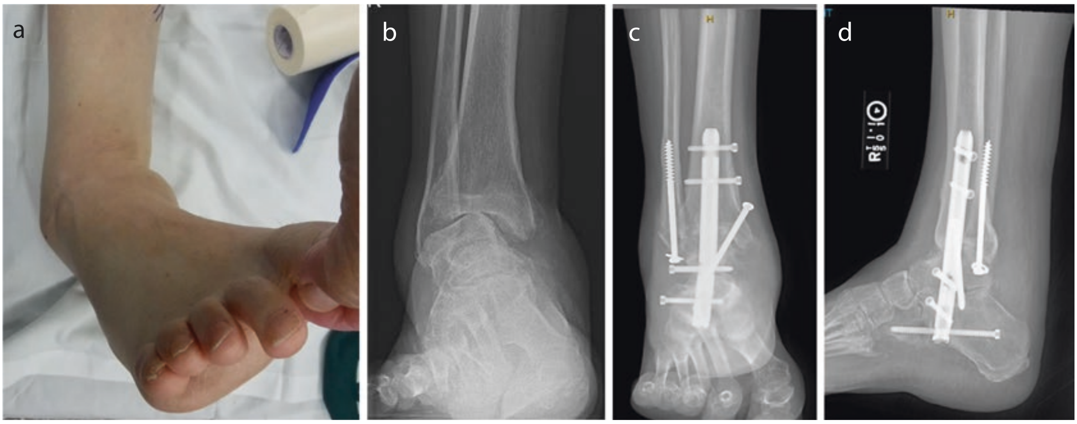

Fig. 7 This 63-year old neuropathic diabetic male developed this deformity after multiple ankle "sprains" (**a**, **b**). Radiographs at 1.5 years following ankle fusion with retrograde locked intramedullary nail and augmented fixation (**c**)

4 Arthrodesis in the Neuropathic Patient with Infection

Obtaining and maintaining a stable ankle reduction is essential to achieve a favorable clinical outcome following treatment of an ankle fracture in the neuropathic diabetic. Failure to achieve and maintain a stable reduction increases the mechanical load on the fixation construct, leading to mechanical failure, tissue break down, and deep infection (Figs. 1 and 2). Accommodative bracing is generally inadequate longitudinally. The patient in Fig. 8 sustained a fracture of the medial malleolus that was initially determined to be stable. The instability was not appreciated until she presented with a limb threatening infection. Treatment required resolution of the infection and stabilization afforded by arthrodesis. This was accomplished by a single stage debridement of the infected bone, and ankle fusion with a circular external fixation construct [9, 29]. A similar situation presented with the patient in Fig. 9 following failure of internal fixation.

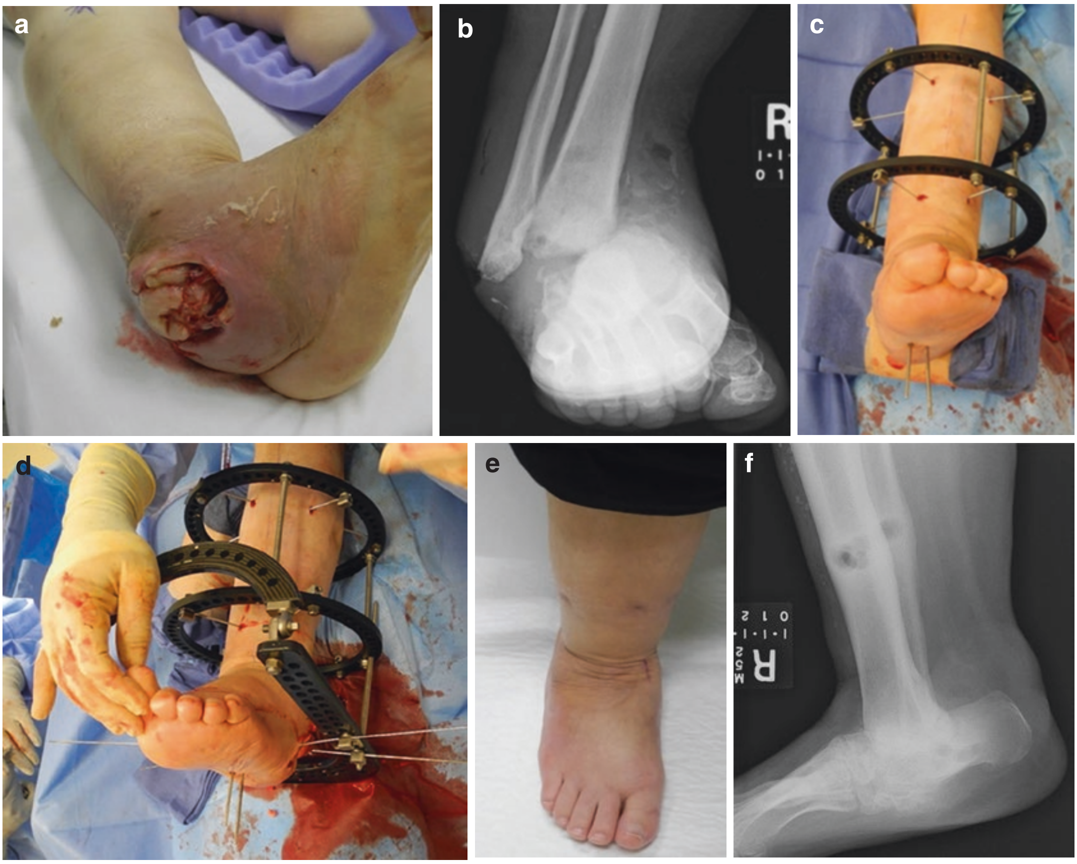

Fig. 8 This 61-year old neuropathic female sustained an unstable fracture of the medial malleolus that was treated nonoperatively in a fracture boot. Photograph and image 6 weeks later when she was referred for amputation (**a**, **b**). The first step in surgery was a debridement of the infected wound, followed by preparation of the ankle joint for arthrodesis. Provisional fixation was accomplished with two transarticular smooth pins. A tibial ring block was applied to the tibia to be used as the "reference" segment (**c**). A closed foot ring was then applied to the foot. The "moving segment" is then attached to the reference segment with either threaded rods of adjustable struts. Compression of the "moving" segment to the "reference" segment creates a stable construct (**d**). Photo and image at 2 years demonstrating successful limb salvage (**e**, **f**)

Fig. 9 This 61-year old neuropathic female presented 6 weeks after a failed attempt at surgical stabilization of an unstable ankle fracture (**a**, **b**). Photo and radiograph at 1.5 years following successful single stage removal of implants, debridement of osteomyelitis, and application of an ankle fusion construct circular external fixator (**c**, **d**)

5 Circular External Fixation to Accomplish Ankle Fusion

Circular external fixation is an excellent surgical technique to accomplish ankle fusion. The basic principles of deformity corrected are employed. In Fig. 8, the tibial mounting block segment is considered the *reference* segment, and the closed foot ring is considered the *moving* segment. Note that percutaneous K-wires were used to achieve provisional fixation. Either threaded rods or compressible struts are used to connect the moving segment to the reference segment. Compression between these two segments provides rigid internal fixation; a conduit to achieve successful bony union. Unique to the diabetic patient population with accepted osteoporosis, threaded half-pins should be avoided due to the high risk for developing a tibial stress fracture [30]. All bony fixation should be accomplished with tensioned wires, following the techniques of Illizarov.

6 Hybrid Fixation

The most recent innovation in the treatment of the neuropathic ankle is the use of hybrid fixation that combines elements of internal and external fixation in the treatment of complex ankle deformity patterns. Various combinations of retrograde locked intramedullary nails, transarticular screws, and circular external fixation have been employed to accomplish this task in the most complex patients (Fig. 10) [31].

Fig. 10 This 41-year old diabetic male with renal transplant developed gross ankle instability following resorption of the body of the talus (**a**, **b**). He underwent tibiocalcaneal arthrodesis. Due to the high risk of failure with either internal or external fixation methods, he underwent "hybrid" fixation with crossed compression screws and neutralization with a circular external fixator (**c**, **d**). This has also been accomplished with a retrograde intramedullary nail combined with circular external fixation [31]. Photograph and radiograph at 2 years (**e**, **f**)

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