CHAPTER **26**

Charcot Neuroarthropathy Reconstruction Using External Fixation: A Long-Term Follow-Up

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INTRODUCTION

Charcot neuroarthropathy is a denervation-induced disease that involves progressive joint destruction predominantly affecting the foot and ankle (1,2). Charcot neuroarthropathy poses an immense challenge to both patient and doctor. There are two proposed theories regarding the etiology of Charcot neuroarthropathy. The German or neurotraumatic theory suggests that repetitive microtrauma due to an insensate foot leads to an insidious cycle of joint breakdown and repair causing microfractures and callus formation. The French or neurovascular theory states that decreased vasoconstriction due to sympathetic denervation leads to increased arteriovenous shunting, which results in hyperemia and increased bone resorption. Some authors believe it is a combination of both theories, in which microtrauma and sympathetic denervation encourage a heightened inflammatory response, which in turn leads to an infiltration of pro-inflammatory cytokines and neuropeptides resulting in increased amounts of receptor activator of nuclear factor-kB (NF-kB) ligands (RANKL) (3-7). This highly intertwined pathophysiological response results in an increase in osteoclastic activity and bone remodeling.

Diabetes mellitus is the number one cause of Charcot neuroarthropathy in the US. The incidence of Charcot neuroarthropathy is not known, but the literature reports ranges from 0.08-13% of diabetic patients (8-13). In addition, many believe that Charcot neuroarthropathy is often missed 25% of the time and therefore the true incidence may be underreported (14). The standard treatment for Charcot neuroarthropathy has been conservative care rather than surgical intervention. Conservative treatment has mainly consisted of offloading, including a total contact cast, Charcot restraint orthotic walker (CROW), and bracing (10,12). Nonetheless, authors have described between a 40% and 60% failure rate with conservative treatment (15,16). Charcot neuroarthropathy is a progressive disease that involves dislocations, fractures, and bony deformities that may potentially lead to ulcerations, osteomyelitis, amputations, and death (17-19). Therefore, treatment needs to be aggressive, as failure to treat Charcot appropriately may have serious consequences.

Reconstructive surgeries for a Charcot foot address multiple aspects of a patient's life including allowing the patient to wear normal shoes and adding stability that assists in the ability to ambulate (20). The patient may return to social activities and to work, which leads to an increased quality of life, decreased depression, and overall increase in health. It is imperative, that as physicians we acknowledge these factors in our attempt to treat the patient as a whole. Unfortunately, there is lack of evidence-based literature that dictates or validates surgical management for Charcot neuroarthropathy. We will present details of 9 lower extremity surgeries to determine if surgical intervention for the Charcot foot may have long term advantages.

METHODS

This retrospective study was executed by accessing and collecting patient data through electronic medical records and questionnaires. Medical records were accessed using Practice Fusion software. The questionnaire utilized was a modified version of the AAOS Ankle and Foot Institution questionnaire, applied to rate ambulation before and after surgical intervention. There were 4 questions that concerned ambulation status with 6 responses on a 1-6 point scale where 1 = good and 6 = bad. For this study, ambulation was rated between 4 and 25, with a score of 25 representing the worst ambulation outcome. Other questions were asked about shoe gear and overall happiness with the surgery. From 2012 to 2015, 9 feet with Charcot (8 patients) were included (4 men, 4 women). Body mass index was obtained from the patient appointments to the clinic in which the height and weight of the patient were taken. All patients underwent Charcot reconstructive surgery using external fixation. Patients either had surgery performed by a podiatrist at Mercy Hospital or a podiatrist at Jackson North Hospital, in Miami, Florida. Both hospitals are connected via a common teaching institution, Barry University. Therefore, patient follow-ups were performed at either of the 2 hospitals.

Surgery was restricted to Eickenholtz stages II and III, or when the patient showed no acute symptoms of Charcot. Indications for surgery also included at least a Brodsky classification 2 and/or 3A. Patient criteria included instability of at least 1 of the rear foot joints (tibiocalcaneal, talocalcaneal, or tibiotalar), as well as severe foot deformity that led to a nonplantigrade foot. Routine external fixation maintenance protocol included weekly follow-up visits for proper assessment of the affected limbs and dressing changes. External fixators were thoroughly cleansed, cleaning each pin with sterile gauze and alcohol. Next, betadine soaked sterile gauze was wrapped around the pin sites. Then, cast padding was used to protect the extremities from the frames, and finally self adhesive tape was used to wrap the frames. Antibiotics were prescribed when infection was suspected, including drainage from pin sites or signs of cellulitis.

The goal of surgery as expressed to the patients was to increase the patient's ability to ambulate in customized orthopedic shoes, with reduced chance of bone and tissue breakdown. The 2 primary outcome markers included in this study were type of footwear, and activity and ambulation level. Secondary outcome measures included duration of frame, laterality, body mass index, sex, revision surgeries, infection, and amputations.

RESULTS

Eight patients (9 feet) were included in this study with 1 patient having surgery performed bilaterally. The average age of the patients was 54 years (range 42-62 years) and 50% were male. A preoperative surgical limb ulceration was present on 3 of 8 patients (Figure 1) and the average body mass index of patients was 31.7. All patients had Charcot due to a diabetic complication. At the time of surgery, all patients were classified as either Eickenholtz II or III, and had some type of rearfoot involvement (Figure 2). The average duration of the frame was 12 weeks.

The most common complication that necessitated revision surgery was pin breakage. Three of the 9 legs (33%) required revision surgery. One patient required stepwise fusion, which included a midfoot fusion, followed by a tibial-calcaneal fusion. This was not counted as a revision surgery because it was part of the original surgical plan.

Postoperatively, 7 of 8 patients were able to wear a diabetic shoe, Arizona brace, or Richie brace and 50% of the patients were able to wear diabetic shoes. One patient still wore a CROW boot, but this was due to an active ulcer. This patient was able to carry out his job as a fisherman; thus, still demonstrating a high activity level. The average follow-up from the date of surgery was 2.8 years, (range 1-4

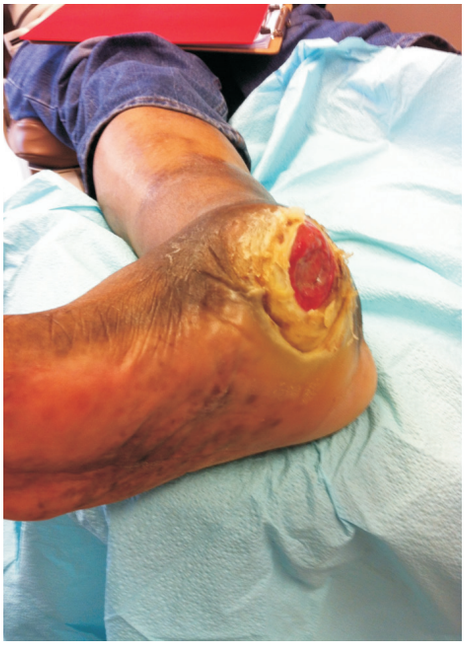

Figure 1. Initial presentation of Charcot foot ulceration. Patient had uncontrolled diabetes with peripheral neuropathy, and severe foot instability, with ulceration over the talonavicular joint.

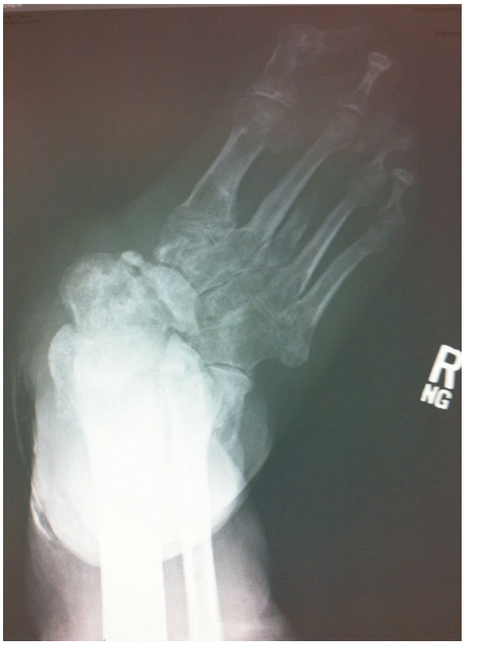

Figure 2. Radiographs of right Charcot foot before the surgical intervention. Global fractures, dislocations, sclerosis, and bony remodeling are evident.

years). Considering prior to surgery, 6 of 8 patients had to wear a CAM or CROW boot regularly, there was an increase in ambulation level noted. According to the modified AAOS questionnaire score, ambulation can be measured on a 25-point scale, the lower the score, the more active the ambulation. The preoperative average score was 26 and the postoperative average score was 6, demonstrating a 20-point improvement. Type of shoe gear can also be measured on a 6-point scale with a lower score indicative of more versatile shoe gear. The preoperative average score was 5 and the postoperative average score was 2, demonstrating a 3-point improvement (Figures 3-7) (Tables 1-3).

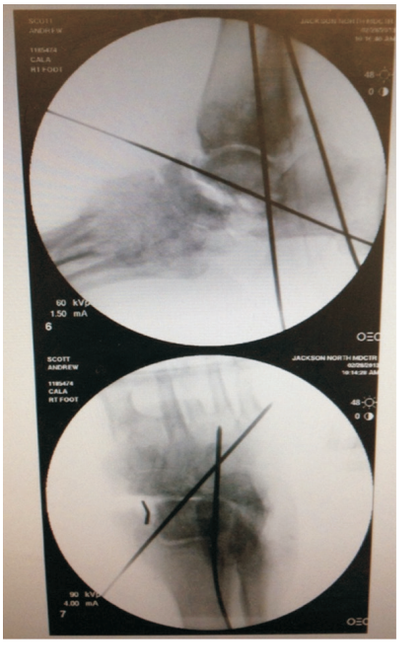

Figure 3. Intraoperative fluoroscopy of Charcot foot. Plantigrade alignment achieved through fusion and stabilization of the affected joints.

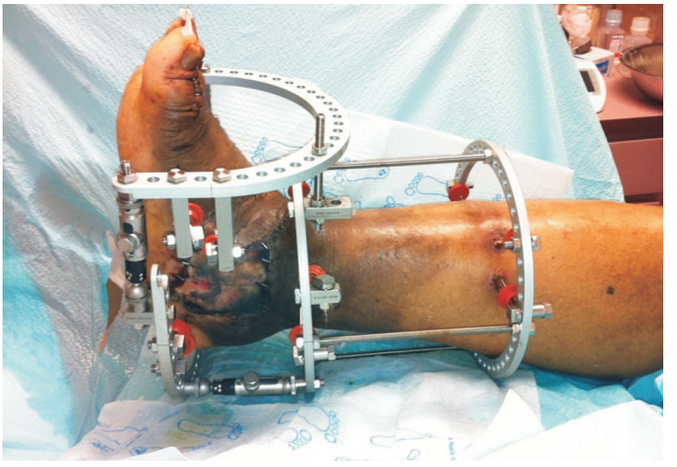

Figure 4. Routine in-office evaluation and cleaning of pins.

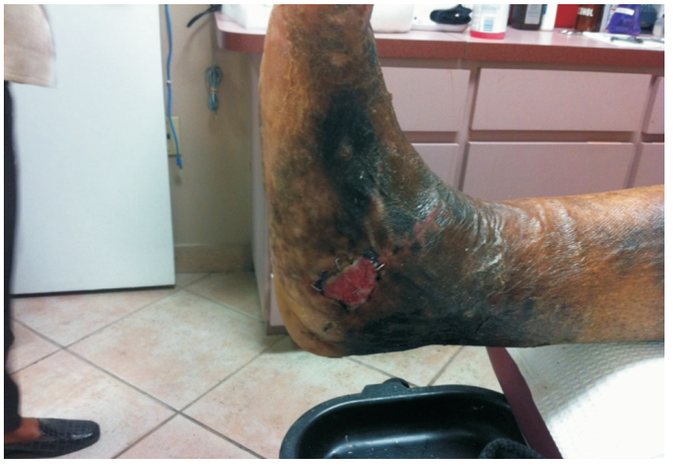

Figure 5. View 1 year after removal of external fixation. The ulcer has been healed.

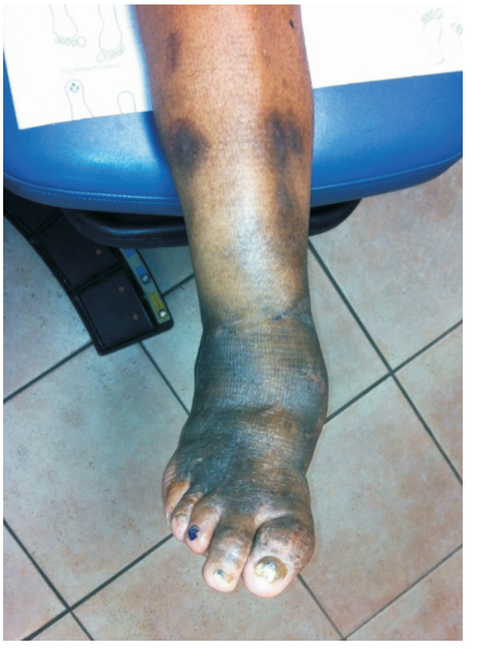

Figure 6. View 2 years after removal of external fixation. The foot still has plantigrade alignment, with no ulcerations.

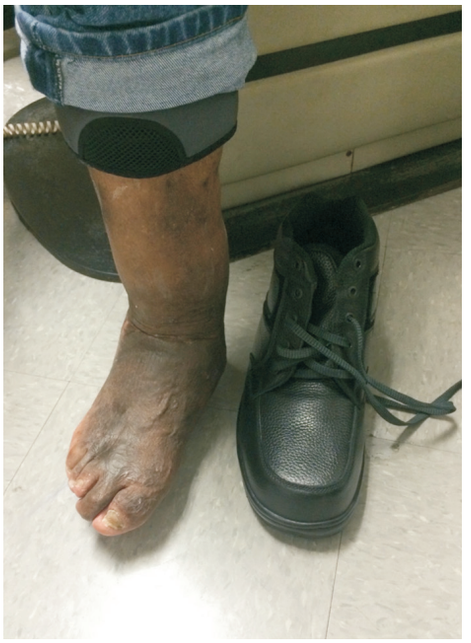

Figure 7. Clinical view 2 years after removal of external fixation. The patient is wearing diabetic shoes.

DISCUSSION

Charcot neuroarthropathy continues to be a chronic disease with poor outcomes, increased morbidity, and decreased quality of life (21). Amputation rates in a patient with a Charcot foot and an underlying ulceration range as high as 28% (22). According to a recently published level II article by Schneekloth (16), in which he examined surgical management of 860 patients with Charcot, approximately 8% of patients who underwent surgery required a major amputation (23). In another recent, systematic review, Lee reported the rate of amputations to be 2.6%, specifically in the external fixation group (16). No amputations were performed after external fixation among all patients in this study. Furthermore, when ulcerations were compared before the surgery to the time of writing this article, there was a 67% healing rate.

One patient in this study had internal fixation that proved to be painful and needed another surgery before undergoing external fixation. A recent literature review reported a 50% increased risk of internal fixation hardware breakage when compared to external fixation in Charcot reconstruction (16). Additionally, our patients had an average BMI of 31.7, and in obese individuals, internal fixation may break over a period of time (16,24). Pinzur has shown that 1-year postoperatively, morbidly obese patients with Charcot foot and external fixation were ulcer and infection free and were able to ambulate in custom

Table 1. Average increase in ambulation level and minimalistic shoe gear preoperatively, and at least 1 year postoperatively.

	Preop	>1 year Postop
Ambulation level (range 1-25)	22	6
Shoe gear (range 1-6)	5	2

Table 2. Results based on the questionnaire.

	Yes	No
Did you regret the surgery?	0	8
Did the surgery increase your quality of life?	8	0

Table 3. Characterstics of the Sample.

Variable	Value	Percentage
No. of patients	8	
Bilateral*	4	50
Left leg	2	25
Right leg	2	25
Male	4	50
Female	4	50
Age, mean ± SD years	54 ± 7.8	
Age range, years	42-62	
Body mass index (kg/m2)		
Average	31.7 ± 5.5	
Diabetes mellitus	8	100
Duration of frame, weeks		
Mean ± SD	12.5 ± 4.5	
Range	8-24	
Followup, years		
Mean ± SD	2.8 ± 1.3	
Range	1-4	
Post-operative shoe wear†		
Tennis shoes	2	
Diabetic shoes	4	
Arizona brace	4	
Richie brace	1	
CROW or CAM boot	1	
No shoes	0	

*Laterality was based on the limb affected, not necessarily on the surgical limb.
† Some patients would interchange shoe gear depending on expected activity level, and therefore numbers added up to more than total number of patients. Questionnaire asked specifically which shoe was worn the most.

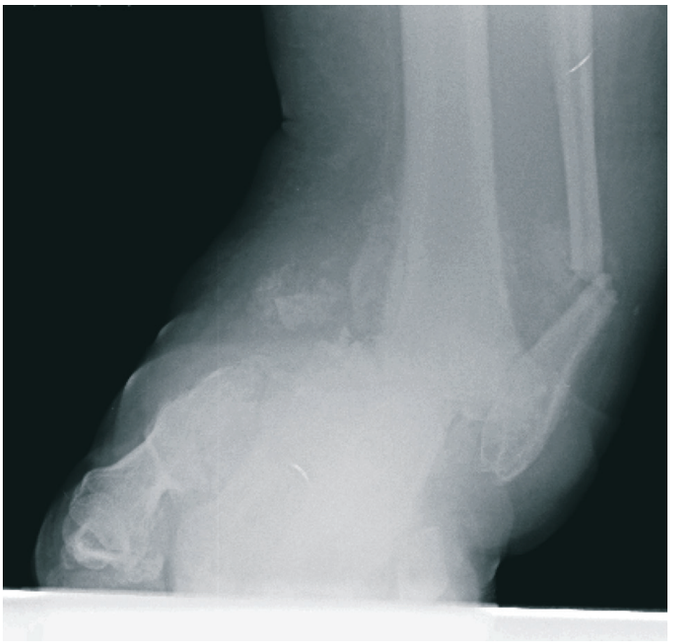

Figure 8. Initial presentation showing multiple fractures, dislocations, and varus position.

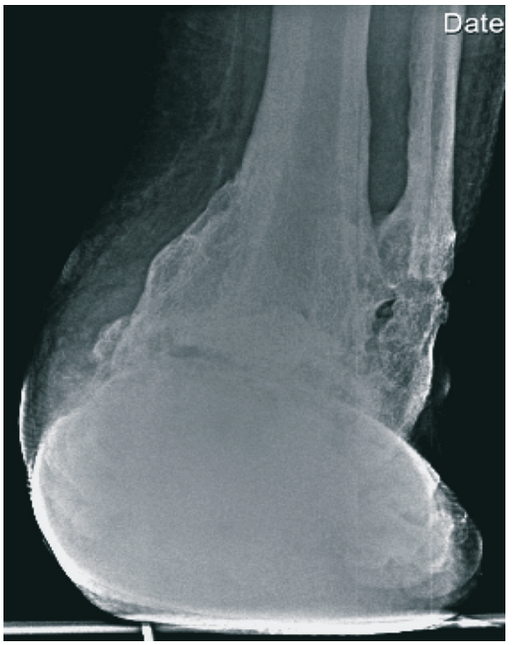

Figure 9. View a 1 year postoperative, with a rectus alignment.

shoes (24). Charcot patients have multiple co-morbidities, such as obesity, osteopenia, and osteomyelitis, which pose a challenge when using internal fixation. Furthermore, revision surgery for internal hardware removal in these patents increases their morbidity risk, particularly since this type of fixation involves large dissections. External fixation can be a favorable alternative when long-term correction is needed in these individuals.

All patients in this study had some type of rearfoot involvement, which implied a greater surgical challenge, in terms of correcting triplanar deformities and protecting adjacent major neurovascular structures. Furthermore, rear foot deformities have a high rate of skin ulceration and infection which can predispose the patient to osteomyelitis (15,27). It was imperative that the rearfoot deformity is fused into proper alignment to allow a stable plantigrade foot, and reduce joint breakdown due to improper biomechanics. All patients stated that there was no deterioration in their ambulation levels, suggesting external fixation and surgical technique provided adequate anatomic reduction, which may have resulted in successful long-term benefits. Eight of 9 patients had radiographic and clinical arthrodesis. However, there was 1 patient with a pseudarthrosis with a stable joint (Figures 8,9), who was able to ambulate normally.

Functional ambulation was improved in all patients more than 3-fold. A score of 25 represented the lowest ability to ambulate, and our study showed an average decrease of 22 to 6. One strength of this study was that the ambulation score took into consideration factors that affected the patient's social life such as the patient's ability to "do the things they wanted to do." Regardless of how deformed the foot may appear, or how severe the radiographic angles appear, and how rectus the foot looks after surgery, all that matters are the effect the surgery had on the patient.

All patients were confident that the surgery improved their quality of life. Some patients reported that they were happy to be able to get out of the house. The ability to walk, and independent living helps with cardiopulmonary health and decreases the chance of deep vein thrombosis and other morbidities (29). As physicians it is imperative that we address the patient as whole, including their mental and social health.

This study also shows that patients were able to maintain the type of shoe gear worn at an average follow-up period of 2.8 years. According to Pinzur and others, the main goal of reconstruction surgery in Charcot foot is "a long-time infection-free ulcer-free foot with the ability to use commercially available depth-inlay shoes and custom-accommodative foot orthoses maintaining a long term walking independence" (27,28). One of the 8 patients had to wear a CAM walker due to an existing ulceration on his foot. His blood sugars were not well controlled. The indication of the CAM boot was to maximally offload the ulcer and offer protection while the patient performed his occupational duties.

With a mortality rate of 68% within 5 years after limb amputation in diabetics, amputation should be avoided at all costs (30). Pinzur has shown a 96% incidence of limb salvage with the use of external fixation alone in the diabetic

Charcot foot patient. Although limb salvage is important, the duration of the limb viability is also very important. This study provides insight into the long-term aspect of external fixation in Charcot reconstructive surgery.

Charcot deformity is usually severe and ranges from person to person. Surgical technique and experience play an intimately essential role in planning of surgery. Therefore, each patient has a unique surgical outcome, dictated by the surgeon, which cannot be measured and is not static from patient to patient. The innate issue of Charcot reconstruction makes randomized, blind-controlled studies very difficult to perform as Charcot foot is very evident and can be considered a medical emergency. The goal is always limb preservation. However, as we continue to shed a light on an evidence-based approach to limb salvage, we can determine what is best for the patient.

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