Limb salvage in Charcot deformity correction: A case series of 20 limbs

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Charcot arthropathy is a disabling complication of peripheral neuropathy, with progressive osseous destruction often necessitating operative intervention to prevent ulceration and even amputation. The prospect of a stable, plantigrade foot is one that is best sought through timely intervention. While a host of procedures and techniques for Charcot reconstruction have been described in the literature, no clear consensus has been reached on a superior method or modality, nor on what factors most significantly affect outcomes and complications. We present a case series of 18 patients (20 limbs) operatively treated at our institution and followed for an average of 3 years for Charcot deformity. Reconstructive efforts consisted of both internal and internal fixation, and combinations thereof. To date, 1 patient has received a below-knee amputation. At 3 years (range 12-50 months), 80% of our limbs have shown that our interventions have provided lasting correction and defense against future ulceration and other undue sequela. Three limbs remain affected by ulceration. In total, 95% of limbs have avoided major amputation. Our results appear comparable with the available literature. While successful results are being achieved in this endeavor, many questions remain unanswered, awaiting higher levels of empirical evidence to aid in their resolution.

Keywords: diabetic foot, arthrodesis, reconstruction, external fixation, beaming, tibiotalocalcaneal fusion, arthropathy

Charcot arthropathy, a potentially disabling complication of peripheral neuropathy, often demands surgical intervention due to the progressive nature of osseous destruction, which, when left unabated, may lead to deformity susceptible to ulceration, infection, and ultimately, amputation. Surgical intervention is often necessary to create a stable, plantigrade foot that is less prone to ulceration. While a host of procedures and techniques for Charcot reconstruction have been described in the literature, no clear consensus has been reached on a superior method or modality, nor has a deformity-specific correction algorithm been established.

In addition to procedural selection, operative timing with respect to stage of deformity has not been clearly defined. Despite this, failed conservative management, recalcitrant ulceration, continued pain secondary to residual bony deformity, and as a final effort to avoid amputation remain the primary surgical indications [1].

The insensate foot is one that is prone to recurrent, unperceived trauma. Continued ambulation, coupled with neuropathic joint relaxation and hypotonia, allows for progressive osseous destruction that compromises the pedal architecture. Loss of vasomotor tone, as a result of autonomic neuropathy, allows shunting within the Haversian system,

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increasing bone perfusion with subsequent demineralization and, eventually, osteopenia. The resultant abnormal bone is ill equipped to protect the vulnerable joints from the aforementioned neuropathic destruction and deformity. As each case of Charcot deformity is unique, largely due to patient physiology and pattern of destruction, direct comparison of fixation techniques and patient cohorts may not be feasible. Despite this lack of standardization, sound understanding of the principles of each surgical technique remains the mainstay of enabling a surgeon to devise a construct that will have the most effectual outcome.

The aim of our study was to review, at midterm follow up, the outcomes of 20 limbs post Charcot deformity correction. We deemed a successful outcome as a stable, ulceration free limb allowing for ambulation. A limb with remaining wound or ulceration, or one that underwent major amputation, was regarded as an unsuccessful outcome.

Case Series

From February 2010 to July 2017, 26 limbs in 24 patients were treated consecutively at our institution for Charcot deformity of the midfoot, rearfoot, and ankle, or combinations thereof, with at least 12 months of follow up available. Our institutional review board approved this retrospective case series. Of these patients, we excluded one patient who was treated at an outside institution between treatments at our institution, one patient who died due to unrelated causes, and 4 others who were lost to follow up as they had not been seen at our institution in over 1.5 years. Inclusion for operative reconstruction included recurrent ulceration despite conservative measures. We prefer to avoid surgical intervention in those with a closed soft tissue envelope though deformities that were deemed unbraceable and neuropathic fractures/dislocations that were complicated by Charcot destruction were also included. We did not elect to perform a reconstruction for any patient who would have clearly been better served with a proximal amputation. In deciding between conservative and surgical intervention, we carefully weighed the risks and benefits of each potential treatment including the location and magnitude of deformity, patient willingness and ability to comply with post-operative instructions, comorbid conditions, glycemic control, vascular status, family support, social issues, wound presence with or without concurrent infection, and others. Notably, reliance on casting/bracing to contain the deformity, skin breakdown, deep vein thrombosis, and contralateral Charcot development are of special concern in patients undergoing conservative approaches. In total, 20 limbs in 18 patients met our study criteria.

In some patients, after successful Charcot reconstruction at a given anatomic location, the patient later incurred a Charcot event at a separate site within the same extremity. In these instances, for calculating wound duration preoperatively and time in external fixation, the total time for all patients combined was divided by the total number of “Charcot events” (and thus reconstructions) rather than number of limbs. This was performed to avoid artificially higher average time intervals that would have been produced by attributing the pre-operative wound time and external fixation time for multiple surgeries to one limb. In total, 24 reconstructions were performed as 4 of the 20 limbs underwent surgical correction of a repeat Charcot event.

A complete review of the medical charts including radiographs were performed to gather the data for our study. In addition to demographic information, the following variables and parameters were recorded: the location(s) of the deformity, primary and adjunctive procedures performed, date of index and subsequent surgeries, presence of wound(s) and osteomyelitis, time to wound healing, wound duration prior to surgery, percentage of patients obtaining a Charcot Restraint Orthotic (CRO) walker post operatively, complications, comorbid conditions, tobacco use, Hg A1C%, prior pedal amputations, date of last follow up, and total follow up time.

Of the 20 limbs, 6 had Charcot deformity of the ankle (Brodsky 3A), 5 had deformity in the rearfoot/Chopart’s joint (Brodsky 2), 17 demonstrated abnormality at the midfoot/Lisfranc joint (Brodsky 1), and 1 patient developed a Charcot process to the calcaneal tuber (Brodsky 3B). Additionally, 5 of these patients presented with combined Brodsky 1 and 2 deformities.

Our patients, on average, were afflicted by 4.3 comorbid conditions. Diabetes was responsible for the neuropathic process in 14 patients, idiopathic causes in 2, spinal stenosis in 1, and Lupus in 1. Eight patients had a history of cardiac disease, 1 of CVA, 3 of COPD, 2 of chronic kidney disease (1 ESRD), 2 of psychiatric disorders, and 3 of hepatitis. Peripheral vascular disease affected 1 patient. Ten patients had a history of tobacco use. The average A1C value in those with diabetes preoperatively was 9.3%.
The average patient age was 55.7 years, there were 9 females and 9 males. Average BMI measured 34.6kg/m².

Operative Procedures

All procedures were performed by the senior author. Two reconstructions were performed during the acute phase of the disease (Eichenholz I), and the remainder were performed during the inert phase (Eichenholz stage II/III), all after distal perfusion had been deemed appropriate.

The index procedures were performed at the location of existing deformity, with subsequent surgery (subsequent Charcot event) performed at the new location of deformity.

Seven patients underwent columnar beaming (example in Figure 4), one medial column plating and screw fixation, one medial double screw fusion, and one medial column screw fusion. All but one of these constructs was augmented with application of a static circular frame. Three underwent plantar midfoot planing with placement of external fixation alone.

One patient underwent bilateral beaming in a staged fashion. The other patient who underwent bilateral procedures was treated for a calcaneal avulsion fracture on the right side with fragment excision, achilles tendon reattachment via anchors, and flexor hallucis longus transfer. Contralaterally, he developed midfoot, and then, ankle deformity, treated sequentially with external fixation and planning and TTC fusion respectively.

Regarding the 5 tibiotalocalcaneal (TTC) fusions, 3 underwent intramedullary nailing. In one such case, nailing initially proved effective but was compromised by late infection. Limb salvage was achieved with the use of a titanium cage after temporization with an antibiotic nail (Figure 1). The other 2 patients underwent lateral TTC plate and screw fixation (Figure 3) constructs respectively, as prior hardware precluded intramedullary nailing. In 4/5 TTC fusions, a static circular frame was applied over the respective fusion construct. Two intramedullary nails were placed after arthroscopic ankle preparation. In these cases, there was not yet flagrant malalignment necessitating an open approach. With open approaches, we formally prepare the subtalar joint with our constructs. The necessity for this has been debated [2].

Two patients underwent medial Lisfranc fusion with external fixation utilizing olive wires and no additional hardware. These were performed for severe dislocations in the acute phase that threatened soft tissue integrity. No limbs underwent concomitant TTC fusion and midfoot bolting as we did not treat a patient with simultaneous deformity. However, 4 patients that received midfoot reconstruction subsequently underwent treatment for deformity at the ankle. An additional patient, who was treated for midfoot disease and then later developed ankle pathology, underwent a below-knee amputation (BKA) for concomitant ankle abscess and systemic sepsis (Figure 2).

The remaining patient underwent ankle fusion by way of external fixation alone given the attendant joint sepsis.

Cases of soft tissue infection were treated with thorough irrigation and debridement with appropriate antibiotic therapy. Osteomyelitis was treated with bone resection as necessary with infectious disease consultation to manage prolonged antibiotic therapy.

Results

Eighteen patients for a total of 20 limbs (2 patients with bilateral reconstructions) were operatively treated at our institution and followed for an average of 3 years for Charcot deformity. Given the 20% rate of a repeat Charcot reconstruction, 24 reconstructions were performed in total (4 repeat Charcot reconstructions for patients who developed ankle disease after midfoot surgery). To date, 1 patient has received a BKA. Overall, 80% of our limbs have obtained a successful outcome. Three limbs remain affected by ulceration, 2 of which had wounds preoperatively. In total 95% of limbs have been salvaged or remain salvageable.

With respect to primary midfoot/hindfoot reconstruction, there were 17 such cases. As mentioned, 5 developed subsequent disease of the ankle, with 3 out of 4 attempted ankle reconstructions obtaining salvage, and in the remaining patient salvage not attempted due to emergent infection (BKA). Of the remaining 12 primary midfoot/hindfoot reconstructions, 10 limbs were salvaged. One patient in this group underwent bilateral midfoot reconstructions in a staged fashion.
This patient incurred separate Charcot events at both the midfoot and then the ankle, approximately 3.5 years apart. Panels a, b show his presentation after his ankle Charcot event. He had been treated by our team with external fixation and planing after a failed midfoot fusion several years prior at another facility. His midfoot hardware was removed and the ankle addressed with TTC nail fusion (c,d), the tract of which can still be appreciated within the tibial medullary canal (k,l). The nail was removed due to a chronic non-union with superimposed late infection (e,f), and a titanium cage was placed (i,j) after temporary fixation with an antibiotic nail (g,h). At last follow-up, a pseudoarthrosis is appreciated about the titanium cage (k,l). Clinical view of patient (m,n,o): A stable, plantigrade foot is demonstrable, despite the pseudoarthrosis, which has been maintained with his CRO Walker. We see him periodically in the clinic for surveillance exams.
This patient underwent Charcot reconstruction of his midfoot during the acute phase of the destructive process, clinical photo in panel a. Deformity appeared isolated to the LisFranc complex but was grossly unstable as evidenced by the divergent pattern of dislocation seen on his ED radiographs (b,c). Given the tenuous soft tissue, we elected to utilize an external fixation only construct to reposition the gross malalignment of the midfoot via olive wires (d,e). The patient coalesced successfully in an acceptable position (f,g). He ambulated ulceration free for 4 months before presenting to the ED with an ankle abscess and in a septic state. No open wounds were present but soft tissue emphysema was seen on x-ray over an area of the medial ankle where an obvious abscess was present (h). An emergent bedside incision and drainage was performed in the ED (i) before he was taken to the operative theater for a guillotine BKA. It appears that when he presented in sepsis he was undergoing a Charcot process about the ankle (h). The relationship of the Charcot event to the abscess is unclear, although we have encountered Charcot flares complicated by abscess without open wounds previously. This example highlights that with Charcot correction, success is never absolute.
Figure 3 This patient was initially treated for a Charcot deformity with plantar planing and external fixation application for a midfoot prominence and resultant ulceration (a). After successfully healing his ulceration and removal of the external fixator, he presented back to the clinic a few months later with a gross varus deformity at the ankle, and lateral malleolar wound, after a period of admitted unprotected ambulation. Radiographs revealed a pathologic bimalleolar fracture and severe varus deformity of the ankle (b,c). As a broken half pin from his prior external fixator obstructed the tibial canal, he underwent TTC fusion via large diameter cannulated screws. The wound was excised through a lateral approach that entailed fibular takedown, subtalar and ankle joint preparation, and corrective cuts to the tibia and talus to realign the rearfoot and ankle to the leg. An external fixator was placed to extend the area of stability beyond the fusion sites (d,e). Radiographs at final follow-up reveal good osseous union to the ankle and subtalar joints with maintained deformity correction (f,g).
As stated, the 4 repeat Charcot reconstructions were patients who developed disease of the ankle after undergoing midfoot reconstruction. Three of these limbs were ultimately salvaged, with 1 afflicted with persisting ulceration. In total, of the 7 patients with ankle deformity, 5 were salvaged. These include the 3 that were successfully reconstructed subsequent to midfoot reconstruction and 2 primary ankle salvages. The 2 remaining patients were the patient relegated to BKA and the patient with failed ankle salvage after prior midfoot surgery.

In 1 patient, calcaneal avulsion repair with FHL transfer was performed successfully on one side with primary ankle salvage performed on the contralateral side at a later date (1 of 2 patients with primary ankle salvage).

In total, there were 20 primary limb reconstructions, 17 of the midfoot/hindfoot, 2 of the ankle, and 1 of the calcaneal tuber.

The average A1C value in those with diabetes preoperatively was 9.3%. The average A1C in those still with unsuccessful outcomes was 8.3%, while in those with successful outcomes averaged 9.7%. Four patients had a history of amputation within the forefoot. Total time in the external fixation device averaged 2.8 months. Twelve limbs (60%) had ulcerations preoperatively, 3 wounds were complicated by underlying osteomyelitis. At the time of frame removal, 10 of the wounds had healed. The other 2 patients with preoperative wounds have maintained their limbs but are still with wounds, 1 with prior osteomyelitis. Average wound time prior to surgery was 11.2 months. Pin tract infections occurred in 6 frames, wires broke in 2, one of which with concomitant infection that prompted premature frame removal. Other complications included 1 abscess formation, 1 case of non-pin tract cellulitis, 1 incision dehiscence, and 1 decubitus ulceration. Descriptive characteristics of the study population can be seen in Table 1.

Figure 4 Example of medial column bolting. A midfoot Charcot process in the quiescent phase as demonstrated by the partial coalescence and lack of bony fragmentation (a,b). Note the plantar subluxation of the midfoot on the rearfoot, most demonstrable at the talonavicular joint (b). Significant osseous resorption is seen at the intermediate cuneiform which is displaced medially along with the medial column (a). Medial column bolting was utilized to restore stability and correct deformity. This was enhanced with the application of a static external fixator to extend fixation beyond the joint segments affected by the neuropathic process (c,d). Radiographs at final follow up reveal maintained correction (e,f). The joints were not formally prepared in this instance, though it has become our preferred technique to do so.
Discussion

Limb salvage rates in patients undergoing Charcot reconstruction are reported with great variability in the literature. With any of these data points, it is important to consider that each surgeon has an individualized selection bias to their respective patient population. While certain indications for Charcot correction have been developed, each cohort is ultimately that surgeon’s unique population deemed appropriate for surgical intervention. As such, there is likely heterogeneity when comparing patient populations undergoing Charcot reconstruction. As previously mentioned, the choice to attempt reconstruction in a patient with Charcot deformity is multifaceted, and often difficult. Zgonis has described the choice between conservative measures and surgical intervention in Charcot patients as the “lesser of two evils” given the significant complications in each [3]. In addition to deciding between reconstruction and non-operative care, amputation is an alternative in many patients. Clearly, limb salvage should not be undertaken in those whose medical status or limited functional capacity would preclude them from ever realizing the benefits of limb salvage. In these patients, this choice can become complex however, as in some patients, the magnitude of the contribution of comorbid conditions versus the limb deformity itself, to lack of function, cannot be easily discerned. No patient in our series requested a below knee amputation, although all patients with Charcot...
joint disease are made aware from initial diagnosis that the limb is at risk for this outcome. As no patient with emergent infection underwent reconstruction, the procedures could be seen as elective.

Domek, et al., demonstrated that among diabetic patients undergoing elective surgery, the average A1C value of those with postoperative complications was 6.29%, compared with 6.11% for those who did not. Each 1% increase portended a 5% increase in complication risk [4]. Though A1C based risk stratification for diabetic patients undergoing elective procedures has been clearly illustrated, these guidelines are not necessarily best interpreted as concrete “cut off” points when deciding to offer a patient Charcot reconstruction, but rather as a valuable prognostic tool to be considered in the entirety of the clinical situation. Furthermore, bracing in the face of severe deformities is impractical. Ramanujam, et al., have shown that in a cohort of 116 patients with Charcot of the foot and/or ankle treated with external fixation, A1C was not associated with risk of amputation or mortality [5]. A1C Averaged 8.16% in their series, somewhat lower than our average. While not an ideal average, the surgeon must contemplate which scenario offers the best propensity for healing; a wound with an underlying structural abnormality in a patient with an A1C of 9%, or a wound without underlying prominence in that same patient. Those in our study with successful outcomes trended towards higher A1C values. Keeping this in mind, there are undoubtedly patients whose comorbid conditions lack a level of control so great that surgical reconstruction is doomed to failure. The diabetic host with ESRD is one such patient that is often cited as being ill-equipped to convalesce successfully after Charcot reconstruction, given the devastating effects of renal disease on bone metabolism [6] and the sheer mortality associated with the disease [7].

With respect to prior amputations, our results showed that half of those with an unsuccessful outcome had a history of prior forefoot amputation. A greater sample size could ascertain whether prior forefoot amputation is truly an independent risk factor for amputation, or rather a reflection of more severe disease processes in these patients.

Increased morbidity has been reported in Charcot reconstructions in the face of ulceration [5], and internal fixation is often avoided in these cases [8].

Regarding wound presence in our cohort, 10/12 (83.3%) patients with preoperative wounds obtained successful outcomes compared to the overall success rate of 80%. Of the 3 patients who remained with ulceration or wound at the end of our study period, 2 had wounds preoperatively.

In considering the success of our interventions, 80% of these patients ultimately achieved the goals of reconstruction, a plantigrade and functional extremity without a predilection for re-ulceration. In measuring the merit of our interventions however, we must also examine the effect of our interventions on those in whom reconstruction has not attained the desired outcome. One patient underwent major amputation as a result of infection not directly related to our intervention. In assessing the 3 patients in whom wound healing has not been achieved, 2 had wounds pre-operatively. The one postoperative wound developed from non-compliance from the patient wedging her external fixator around her wheelchair footrests to create a decubitus heel ulceration. No wounds were complicated with infection at last follow up. We feel that while 100% success has not been obtained, we have stayed true to the bioethic of non-maleficence or “Primum non nocere”. All 3 of these limbs remain salvageable, and a non-healing wound was never created by our surgical approach.

While the risk of contralateral Charcot after an initial event is well documented in the literature [3], less information has been assembled on the risk of a Charcot event within the same limb at a secondary location. In our series, 5 patients (25% of limbs) developed ankle Charcot deformity after having undergone treatment for breakdown at the midfoot level, comprising 5/17 of all patients treated for midfoot disease. One had been treated with bolting of the midfoot, 3 with external fixation alone, and 1 with plating. Of these 5 patients, 4 admitted to a period of non-compliance with their CRO walker, and 1 had declined CRO walker fitting and instead ambulated in a custom-made gauntlet AFO. On average, the Charcot events were separated by 2.3 years. Given our sample size, we cannot speculate on the potential risk for a repeat Charcot event within the same limb. Clearly, it would stand to reason that if one segment of the pedal framework is fused, the adjacent segments are placed under increased demand, and thus at increased risk for overload and collapse. To what extent this is true and the relationship between various anatomical zones remains to be seen [9]. Increased understanding of ipsilateral Charcot events could potentially affect future fixation methods. To our knowledge, the percentage of this occurrence has
not been documented. Our rate of 25%, while seemingly high, does not have a reference standard for us to compare our outcomes. Perhaps our results are an aberration, or non-compliance was the culprit, or perhaps our follow up of 3 years was simply long enough to realize a potentially underreported sequela. The rate of contralateral Charcot has been reported to be approximately 25%, [10] matching our value for ipsilateral deformity. In our population, 2 patients were surgically treated for contralateral deformity, however more potentially had contralateral Charcot deformities that were treated conservatively, so we did not attempt to compare rates of contralateral versus ipsilateral Charcot in our own series. One of our patients with bilateral deformity at the midfoot level was treated successfully on one side, but remains with an ulceration on the contralateral extremity.

While we routinely obtained radiographs after Charcot reconstruction, we did not include rates of union in our series. LaFontaine has described the abnormal character and cellularity of this bone [11]. This type of bone not only demands more robust fixation, but also has suboptimal reparative capacity. At times, unconventional fixation is required, as in our TC fusion with a titanium cage. This method is touted to facilitate osseous formation through structural mechanics rather than through copious biologics. Via load transfer and its open architecture allowing for graft incorporation, the device is said to actively participate in the healing process [12]. In the absence of radiographic evidence of hardware failure or frank peri-implant fracture, we deem clinical union to be of greater importance in determining weight bearing progression in Charcot patients. Wiewiorsky, et al., elaborated that complete osseous union is not a definite prerequisite for stability [9]. All wound-free patients in our series were instructed to advance to weight bearing in a CRO walker once clinically stable. All but 3 of our wound free patients obtained a CRO walker device. At our institution, we routinely have patients fitted for a CRO walker in the post anesthesia unit after frame removal. Coordination of this effort preoperatively with the prosthetist is key to minimizing the patient’s time to obtaining the device, and therefore their risk of collapse. While waiting for their custom device to be manufactured, a fracture boot is utilized for weight bearing in a controlled environment such as the home or a rehabilitation facility.

With regard to fixation options, progress has been made to discern the general trends and outcomes with various fixation methods, but also to develop and refine techniques for improved success.

Dayton, et al., in their systematic review comparing internal and external fixation for Charcot deformity, presented general concepts of fixation methods [8]. They elaborate that internal fixation has a greater degree of comfortability, being a technique surgeons are most often more familiar with and perceive as being more straightforward. External fixation, while potentially more technically demanding, offers a less invasive approach that ultimately yields a platform for soft tissue preservation while allowing an adjustable design with a wide range of stability.

Their results elucidated several trends in fixation choice. They noted internal fixation tended to be the method of choice when ulceration or osteomyelitis were absent. In contrast, external fixation was most often employed when osteomyelitis or wounds were present. This method was also often staged to afford limb salvage and allowed for earlier weight bearing. Overall, the odds of success with internal fixation was 0.52 times as likely as with external fixation, despite the higher usage of external fixation in more complicated cases.

While internal and external fixation each have merits of their own [1,5] combining the two methods may provide a more favorable outcome [13,14]. Hagewald, et al., in a series of 22 patients with Charcot deformity without osteomyelitis, were able to attain a 91% incidence of short term (58 weeks) limb-salvage utilizing a combined approach. Flap closure was used for wound coverage in the 8 patients with ulcerations [14].

Lamm and colleagues obtained impressive results with a novel two-stage approach to midfoot Charcot deformity correction [15]. Their protocol first obtains correction through gradual distraction and realignment with a Taylor Spatial Frame. Prior to application, a percutaneous Gigli saw osteotomy is performed across the coalesced midfoot to allow for manipulation of the forefoot on a fixed hindfoot, utilizing wires affixed to the frame on either side of the osteotomized segment. This correction is successively maintained with a minimally invasive arthrodesis technique consisting of percutaneously inserted partially threaded, cannulated, intramedullary metatarsal screws after frame removal. The guidewires are used to stabilize the foot before the frame is removed.
All patients underwent Ilizarov external fixation, with additional internal fixation at the location(s) of deformity and bone resection as needed. The authors contend this approach may be especially beneficial in those patients with bone quality insufficient to rely solely on internal fixation, thus requiring stabilization away from the internal site of correction. While the results of dual fixation appear promising, a recent systematic review did not reveal any added benefit of combined fixation [16].

One of the tenants of the Charcot reconstruction “superconstruct” is to extend the area of fixation beyond the osseous segments affected by the neuropathic process [17]. In many of our constructs, a static circular fixator fulfilled this objective whether in isolation or combined with internal fixation. Combined fixation was utilized in 14/24 (58%) of our reconstructions.

In a review of the Charcot literature in the last 5 years, it would seem that the most common location of deformity undergoing operative intervention is that of the hindfoot and ankle [16]. There appears to be a reduced trend for surgical treatment of midfoot Charcot deformity. Lamm advocates primarily for non-operative care in Charcot deformities limited to affliction at the Lisfranc complex, given the inherent anatomic stability at this location [18]. In our current study, two patients with isolated Lisfranc deformity were treated surgically. The remaining patients with Lisfranc degeneration also had pathology at the more proximal midfoot and Chopart’s joints that warranted remedial alignment with fixation.

Our study had a number of limitations. The most notable methodological weakness is the retrospective nature of the design. Two authors were responsible for gathering, compiling, and analyzing data from the patient medical records. This could have inadvertently increased the potential for bias in our results. Additionally, this method is somewhat limited by the accuracy and quality of documentation. However, the patient records were thoroughly reviewed by each of the two reviewing authors independently, and a unified agreement was reached regarding any discrepancies. Given our sample size and the diversity of fixation methods and deformities, we could not set out to correlate various patient factors, types of fixation, and deformity level, to the obtained outcomes. The heterogeneity of Charcot deformity both in pattern of deformity and temporality of presentation, together with each unique host, render such undertakings of outcome based comparisons arduous, requiring a multitude of patients. Rather, we contend we have shown that in a high risk patient population affected by Charcot deformity, limb salvage efforts are effective and without undue sequelae. Indeed, high quality randomized controlled trials are not likely warranted or ethical [19]. The systematic review of Schneekloth appears to agree with this sentiment [16]. The authors report that while the overall quality of literature regarding this topic has improved greatly in recent years, evidence concerning the timing of treatment and the use of different fixation methods remains inconclusive. As a whole, they found that approximately 9% of patients undergoing Charcot reconstruction will undergo major amputation.

In summary, 80% of our limbs have obtained successful outcomes at a follow-up of 3 years, providing vivid examples of how Charcot deformity is amenable to, and even mandates a diverse surgical repertoire to obtain a stable, ulceration free limb. In this approach, the utility of external fixation cannot be understated given the increased propensity for limb salvage [8]. We theorize that this approach, together with more aggressive soft tissue coverage, will offer the highest potential for success. Further research may provide the surgeon with greater knowledge with which to temper their decisions rather than to develop an accepted protocol or gold standard of treatment [19]. Increased understanding of the risk for a secondary Charcot event after reconstruction may be a pivotal factor as well. Given these methods and findings, we hope to better arm the reconstructive surgeon for this formidable task. With ongoing treatment, patient recruitment, and analysis, we aspire to develop this work into one which can more clearly aid the limb salvage specialist in their decision making amongst a host of surgical options.

References

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