Case Reports and Series

Use of femoral head allograft for tibio-talo-calcaneal arthrodesis for a collapsed talus in ankle Charcot neuroarthropathy: A case study with 10-year follow up

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Abstract

Charcot neuroarthropathy is a progressive condition characterized by joint dislocations, pathological fractures and debilitating deformities. This pathology occurs most commonly in the joints of the foot and ankle. A 36-year-old male with peripheral neuropathy presented with progressively worsening right ankle pain. He rated his pain at 9/10 on the VAS (visual analog scale). Physical examination of the right lower extremity revealed a significant rearfoot valgus, zero degrees of ankle and subtalar joint range of motion, and a three-centimeter shortening of the right lower extremity. Radiographs additionally demonstrated talus collapse with obliteration of the talar body. The patient's symptoms failed to improve with conservative care given the progressively worsening nature of the patient's pathology, and surgical intervention was planned. Due to the advanced Charcot arthropathic degeneration, fragmentation, talar body collapse, limb shortening, and contracture of the gastrocnemius, TTC (tibio-talo-calcaneal) arthrodesis with the use of allogenic femoral head and retrograde intramedullary nailing with a gastrocnemius recession, all followed by application of an external ring fixator was employed. Following surgical intervention, a stable, plantigrade foot was noted with optimal positioning at the ankle joint. At ten-year follow-up the patient reported complete resolution of pain with no complications or recurrence of deformity. This highlights that TTC arthrodesis with FHA (femoral head allograft), when performed in the appropriate patient and setting, can correct deformity, restore limb length, prevent or delay limb amputation, and improve patient functionality and quality of life.

Introduction

Charcot neuroarthropathy, originally described by French neurologist Jean-Martin Charcot, is a progressive condition characterized by joint dislocations, pathological fractures and development of debilitating deformities. Currently, diabetes mellitus is reported as the most common etiology of the condition; however, Charcot neuroarthropathy remains a risk for any individual suffering from peripheral neuropathy due to any underlying etiology. The exact mechanisms and pathogenesis are not completely understood but multiple theories exist regarding the development of Charcot neuroarthropathy and have been extensively described in the literature. These theories include the neurovascular theory supported by Volkmann and Virchow, and the most recently proposed inflammatory theory involving the RANK/RANKL/OPG signaling pathway responsible for osseous metabolism and turnover. Additionally, it is widely accepted that a multifactorial combination of the above proposed theories occurs resulting in the development and further progression of the disease process.

Patients with Charcot neuroarthropathy typically present with physical examination findings including localized erythema, calor, and edema to a unilateral foot or ankle, with or without structural deformity, and an associated history of peripheral neuropathy to the affected extremity. The varying degree of physical exam findings determines the staging and classification of a particular individual’s pathology. The modified Eichenholtz classification is the most widely used system for clinical staging, while Brodsky is the most widely used system for anatomic staging. The Sanders and Frykberg classification is also frequently cited for anatomic purposes.
This pathology can occur at any joint, but is most commonly encountered in the weightbearing joints of the foot and ankle.\textsuperscript{1} The most commonly involved site is the tarsometatarsal (Lisfranc) joints of the midfoot, which is affected in approximately 50\% of cases of Charcot neuroarthropathy.\textsuperscript{4} Incidences of ankle, talonavicular, and calcaneocuboid Charcot neuroarthropathy are less commonly encountered but do have a reported prevalence ranging between 10\% and 20\% of cases.\textsuperscript{5,6,7} Despite not being as prevalent as its midfoot counterpart, the presentation of a patient with ankle Charcot neuroarthropathy is accompanied by a myriad of clinical and surgical challenges. These must be appropriately addressed in order to maximize the opportunity to achieve the best possible outcome for the patient and prevent or delay limb amputation.

Incidences of Charcot neuroarthropathy involving the ankle have a higher likelihood of resulting in significant and debilitating deformity and are thus more likely to necessitate surgical correction.\textsuperscript{8,9} A combination of surgical procedures have been described in the literature for management of Charcot neuroarthropathy in the foot and ankle, but the ultimate goal of surgery is to achieve a stable, braceable, plantigrade, and functional limb. Prevention of amputation is vital to ensuring long term clinical success for patients as limb amputation results in increased extremity compared to the asymptomatic contralateral limb.

Perhaps the biggest challenge when encountering Charcot neuroarthropathy of the ankle is the resulting loss of limb length due to the degenerative effects on the talus. A unique way to address this has been described in the literature by Cuttica where the residual ankle joint is prepared with an acetabular reamer to allow for the insertion of a bulk femoral head allograft, which prevents excessive limb shortening and allows for a more optimally functioning limb.\textsuperscript{12} Studies by Rabinovich and McCoy have demonstrated increased functional deficits in patients with a limb length discrepancy of greater than 2.5 cm, highlighting the importance of limb length maintenance.\textsuperscript{10,13}

The authors of this paper were faced with the surgical challenge of managing a patient who had advanced Charcot neuroarthropathy of the ankle joint characterized by collapse of the talus and painful hindfoot valgus. The aim of this case report is to share their results for this challenging surgical patient and to discuss the effectiveness of appropriate bulk femoral head allograft use in the setting of ankle Charcot neuroarthropathy reconstruction.

Case report

A 36-year-old male with pronounced peripheral neuropathy secondary to diabetes mellitus type 2 presented to clinic with a chief complaint of worsening right ankle pain over the course of the previous 5 years. He denied any inciting event or previous history of trauma. The patient rated his pain at 9/10 on the visual analog scale. Past medical history was unremarkable aside from his type 2 diabetes mellitus complicated with peripheral neuropathy. On physical examination an elevated BMI of 37.5 kg/m\textsuperscript{2} was noted. Dermatological examination was unremarkable. Vascular examination revealed palpable pedal pulses and a capillary refill time of less than 3 s to the digits. Neurological examination revealed diminished peripheral sensation to light touch and a 0/10 Semmes–Weinstein monofilament examination bilaterally and sensation was reestablished for the patient at the level of the anterior ankle. Musculoskeletal examination revealed numerous significant findings including: pain to palpation of the right ankle circumferentially, crepitus of the right ankle joint during passive and active range of motion, decreased right ankle joint dorsiflexion, with a maximum dorsiflexed position of negative 20\° with the knee extended, a resting calcaneal stance position of 20\° valgus of the right hindfoot, complete collapse of the longitudinal medial arch, and a 3 cm shortening of the right lower extremity compared to the asymptomatic contralateral limb.

Initial radiographic examination consisted of weight bearing right foot and right ankle films. The foot series demonstrated decreased calcaneal inclination angle of 5\°, and increased talar declination angle of 35\°, an anterior break of the cyma line, increased talar head uncovering, and an increased cuboid abduction angle, all of which are findings consistent with a pes planus architecture, as to be expected given the patient’s physical examination. AP (Anteroposterior) and lateral ankle films additionally demonstrated approximately 50\% talar collapse with oblitera-
tion of the talus body, significant tibiotalar and subtalar joint valgus and advanced degenerative changes of the tibiotalar and subtalar joints including peri-articular osteophyte formation, subchondral cyst development, and severe asymmetric joint space narrowing (Fig. 1). These radiographic findings, when combined with the clinical presentation of the patient, were consistent with Charcot neuroarthropathy of the right ankle joint.

Conservative treatment was employed which consisted of bracing and immobilization, physical therapy, and oral and topical non-steroidal anti-inflammatory therapy, measures which provided temporary mild symptom relief. These measures were limited in their ability to prevent

![](image)
worsening of the deformity and non-sustainable long-term given the progressive nature of the pathology. As a result, the patient continued to develop a progressively worsening hindfoot valgus deformity. Conservative treatment modalities were unable to provide sufficient relief any further, and a CT of the right hindfoot and ankle was ordered for surgical planning.

The CT of the right ankle demonstrated findings consistent with advanced osteoarthritic and degenerative changes to the tibiotalar and subtalar joints including fragmentation, asymmetrical joint space narrowing, osteophyte formation, and significant erosive and cystic changes of the calcaneus, talar body, and distal tibia (Fig. 2). Additionally, the CT 3D reconstruction of the right lower extremity demonstrated a remarkable amount of talar collapse and erosion, which becomes especially pronounced when compared to the asymptomatic contralateral limb of the patient (Fig. 3).

Taking into account the physical exam, radiographic, and CT findings, the patient was scheduled for TTC arthrodesis with bulk femoral head allograft and retrograde intramedullary nailing in conjunction with a gastrocnemius recession, followed by the application of an external ring fixator. On the operative day, the patient was brought into the operating room and placed on the operating table in the supine position with an ipsilateral hip bump placed to internally rotate the operative extremity. General anesthesia was induced and a pneumatic thigh tourniquet was utilized for hemostasis. Attention was first directed to the posterior aspect of the right leg which was raised from the operating table to gain access to the gastrocnemius aponeurosis. A 3 cm incision was made and carried through subcutaneous tissue and the gastrocnemius tendon was incised in a Strayer type fashion while concomitant gentle dorsiflexion was applied to the right foot. Following the procedure, the right ankle was noted to have a maximum dorsiflexed position of 10°. Attention was then directed to the anterior aspect of the right ankle where a longitudinal linear incision of approximately 12 cm was made lateral to the tendon of tibialis anterior and medial to the tendon of...
of the extensor hallucis longus. The incision was meticulously deepened through subcutaneous tissue and vital neurovascular and tendinous structures were protected. The extensor retinaculum was then identified and incised and the anterior ankle capsule was reflected in order to gain exposure to the ankle joint. The talar dome was noted to exhibit significant osseous erosion and articular fragmentation with numerous loose bodies occupying the joint space. The remnants of the non-viable, fragmented, and degenerative talus were then excised and the residual hindfoot structures of the ankle and subtalar joints were then prepared with the use of an acetabular reamer in order to create a cavity for the femoral head allograft. Initially a size 36 mm acetabular reamer was used, and reaming was continued up to a size 44 mm acetabular reamer in 2 mm increments. This preparation method allows for proper insertion of the decorticated allogenic femoral head. These principles follow the “cup-and-cone” technique originally described by Cuttica et al. which has demonstrated an increased ability to maximize the total surface area contact between the allograft and the prepared residual hindfoot structures, maximizing the opportunity for vascular ingrowth and osseous consolidation.12

Following preparation, the decorticated bulk femoral head allograft was placed within the ankle joint. Pre-operatively, the height of the contralateral talus body was measured from the distal aspect of the medial malleolus to the sinus tarsi of the subtalar joint on a standard weight-bearing lateral radiograph. This measurement was utilized to ensure an equal post-operative limb length of the surgical ankle was achieved following interposition of the femoral head allograft. The hindfoot was then optimally positioned in neutral in both the sagittal and transverse planes, and in 5° of valgus in the frontal plane. This position was then temporarily fixated with a Steinman pin and correct positioning and alignment were confirmed with the use of intraoperative fluoroscopy. The plantar entry point for the intramedullary nail was identified, through the center of the calcaneus, exiting the center of the femoral head, and into the center of the distal tibial diaphysis. A guidewire was then passed through the calcaneus, femoral head allograft, and distal tibial plafond as the foot was secured and confirmed to be in correct position with the use of intraoperative fluoroscopy. The osseous structures were reamed with flexible reamers up to 11.0 mm. An intramedullary nail was then introduced in a retrograde fashion, and once again correct positioning and alignment was confirmed with the use of intraoperative fluoroscopy. The intramedullary nail was seated 5 mm above the plantar cortex of the calcaneus. The intramedullary nail was then secured with 2 tibial, a posterior calcaneal, and a subtalar joint screw. This was then followed with the application of an external fixator device to the right lower extremity for further stabilization of the surgical limb.

Post-operative radiographs demonstrated proper placement of the femoral head allograft and all associated fixation with a noticeable restoration of both the medial arch height and limb length with correction of the hindfoot valgus deformity (Fig. 4).

Following the procedure, the patient underwent successful and uncomplicated removal of the external fixator device and was permitted to begin partial weight bearing in a CAM boot. Radiographs at this time continued to demonstrate stable surgical fixation with continued visualization of a stable and plantigrade limb (Fig. 5). The patient at this time relayed 0/10 pain on the visual analog scale and expressed incredible gratitude as it was the first time he had a straight foot and limb in years.

16 weeks post-operatively, the patient returned to clinic for further evaluation and was noted to be fully functional in a CAM boot, with continued 0/10 pain. Additionally, physical examination at this time demonstrated rigid stability of the surgical site and maintenance of the restored medial longitudinal arch height and limb length restoration to the right lower extremity. Radiographs demonstrated additional osseous consolidation across the arthrodesis site and continued stability of the surgical hardware. The patient was subsequently transitioned from the CAM boot to supportive shoe gear with an ankle brace, and promptly started physical therapy with modalities specific to improving balance, strengthening the lower extremity, and gait retraining. Of note, the patient was recommended to utilize a CROW (Charcot Restraint Orthotic Walker) boot, however refused given his excellent functional ability in supportive shoe gear.

Fig. 4. Immediate post-operative AP and lateral ankle radiographs demonstrating appropriate placement of the femoral head allograft and all implanted hardware.
At one year post-operatively, the patient continued to relay 0/10 pain to the right lower extremity and stated he was able to perform all activities of daily living without limitations or difficulty at this time. Radiographs continued to demonstrate intact surgical hardware with increased consolidation across the surgical site and no signs of deformity recurrence.

At 2-years post-operatively, the patient returned for follow up continuing to be fully functional and pain-free to the right lower extremity, which also continued to refrain from deformity recurrence and continued to demonstrate maintenance of the surgically restored limb length. However, radiographs demonstrated failure of the intramedullary nail at the level of the subtalar joint screw fixation. Given the patient’s radiographic findings of increased osseous consolidation and clinical exam findings of a stable and plantigrade extremity, combined with a lack of subjective complaints, the decision was made to leave all hardware intact and continue to monitor the patient conservatively.

At 5 years post-operatively the patient continued to function pain-free and continues to demonstrate no signs of deformity occurrence. Radiographs continue to demonstrate increased consolidation at the surgical site and no evidence of further hardware failure or displacement.

This all remained true for the patient at the 10-year post-operative follow up where radiographs show further osseous consolidation without evidence of deformity recurrence (Fig. 6). Clinically the patient continued to demonstrate restoration of the medial longitudinal arch, restoration of his limb length, and lack of hindfoot valgus deformity recurrence, all while continuing to be fully functional and pain free.

Fig. 5. AP and lateral ankle radiographs following removal of the external fixator device 10 weeks post-operatively.

Fig. 6. AP and lateral ankle radiographs demonstrating osseous consolidation and maintenance of a rectus rearfoot alignment 10 years post-operatively. Bony fragmentation to the anterior ankle is radiographically appreciated however is clinically asymptomatic.
This shows that both the failure of the intramedullary nail visualized on radiographs failed to have a negative impact on the patient’s overall outcome to date.

Discussion

As previously discussed, incidences of Charcot neuroarthropathy involving the ankle have an increased likelihood of resulting in significant deformity necessitating surgical correction. Factors described by both Game et al. and Rogers et al. go on to further support this narrative, as well as elaborate on the involved pathophysiology. Game et al. explained that the combination of continued ongoing pressures of the pedal structures combined with the underlying neurological sensory deficits results in unremitting trauma to the osseous and soft tissue structures, further contributing to deformity development. Rogers et al. additionally demonstrated that cases of hindfoot or ankle Charcot neuroarthropathy have a higher likelihood of developing and resulting in significant deformity that in unable to be effectively braced and offloaded, and therefore necessitate surgical intervention.

When discussing surgical interventions, it is crucial to set appropriate expectations. This is especially true when defining success in reconstructive procedures in the presence of Charcot neuroarthropathy. Ultimately, these interventions are considered to be limb salvage in nature. Studies by both Jeng et al. and Rogero et al. go on to further support this narrative, highlighting the importance of providing a functional limb and delaying or avoiding below knee amputation. When this is achieved, intervention should be considered successful in this challenging patient population, especially when considering the well documented mortality rate associated with non-traumatic below knee amputations, which has been reported to be as high as 82% within 5 years post-operatively.

A functional, plantigrade, and pain-free limb was achieved for our patient in this case, and maintenance of the correction has lasted over 10 years to date, without any signs of deformity recurrence. The interposition of the bulk femoral head allograft is largely responsible for this success. The use of the femoral head allograft was crucial as it addressed a 3 cm limb length inequality due to the significant collapse of the talar body and subsequent acquired hindfoot valgus deformity. Hartog et al. commented on the importance of femoral head allograft interposition for maintaining hindfoot height and subsequently decreasing the likelihood of gait impairments. In his study five patients underwent TTC arthrodesis with femoral head allograft, four of which went on to have excellent relief of their preoperative pain without loss of limb length. However, his patient’s follow-up time was a mean of just 1.5 years. According to McCoy et al. limb length inequalities of greater than 10 mm contribute to functional deficits. Rabinovich et al. further goes on to state that greater limb length discrepancies are associated with higher rates of non-union. Additionally, Coetzee et al. demonstrated a significantly higher fusion rate as well as better functional outcomes with the use of femoral head allograft in cases of ankle and TTC arthrodesis when compared to conventional ankle and TTC arthrodesis without allograft interposition. Therefore, correction of the three-centimeter limb length inequality that our patient demonstrated was imperative and ultimately achieved with the use of bulk femoral head allograft.

In summation, a patient with Charcot neuroarthropathy of the ankle failed conservative treatment and underwent TTC arthrodesis with bulk femoral head allograft interposition. The intervention resulted in a stable, plantigrade, and fully functional limb while correcting a severe hindfoot valgus deformity and three-centimeter limb length inequality, restoring the patient’s anatomical alignment. This correction has been maintained for 10 years to date and the patient has been pain free without recurrence of deformity or complications within that time frame. We believe this demonstrates that TTC arthrodesis with bulk femoral head allograft, when performed in the appropriate patient and setting, can delay the need for amputation, reduce morbidity and mortality, correct significant deformity, and drastically improve both patient functionality and quality of life.

Financial disclosure

None reported.

Informed Patient Consent

Complete informed consent was obtained from the patient for the publication of this study and accompanying images.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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