Samuel Merritt University and the California School of Podiatric Medicine (CSPM) salute the CSPM student leaders and podiatric medical students for their efforts in publishing the National Foot & Ankle Review.

“Developing the potential of our students to continue the tradition of assuming leadership positions in the profession is an important facet of the CSPM mission. As Dean, I look forward to supporting and expanding that effort.”

- John Venson, DPM
Dean
California School of Podiatric Medicine
NATIONAL FOOT & ANKLE REVIEW

Staff 2013-2014

Editorial Staff

Editor-In-Chief
Francesca M. Castellucci-Garza, M.S.
Elizabeth Tronstein, M.P.H.

Co-Editors
Matthew Doyle, M.A, M.S.
Silpa Joy, B.S.
Anubha Oberoi, B.S.
Dara Taeb, B.S.

Faculty Advisor
Albert E. Burns, D.P.M.

JOURNAL INFORMATION

Editorial Comment
All expressions of opinion and all other statements are published on the authority of the writer(s) and are not views of the National Foot and Ankle Review or its editorial staff. All articles are original content and have not been published elsewhere. Submissions are accepted from all schools of podiatric medicine per journal guidelines. For information about next year’s edition, please see contact information below.

Inquiries
Mailing Address:
National Foot and Ankle Review
California School of Podiatric Medicine
c/o Editor-in-Chief
450 30th St. Suite 2860
Oakland, CA 94609

Email
Direct to Editor-in-Chief
francesca.castellucci@samuelmerritt.edu
elizabeth.tronstein@samuelmerritt.edu
A NOTE FROM THE EDITORIAL STAFF:

It has been a pleasure serving as the editorial staff for the National Foot and Ankle Review 2013-2014 edition. This project required many hours of dedication to both editing and organizing. It has been a challenging and rewarding experience for all of the staff. We would like to thank each of the student writers for their time and effort in their submissions. The journal is only possible with the commitment of students willing to promote academic knowledge and research in the field of podiatric medicine. We are proud to have students willing to partake in this endeavor and wish them continued progress and success in future research.

We would also like to thank Dr. Albert Burns for his continued support of the journal. Without his guidance, time, and effort the journal would not have been possible. Additionally, we would like to thank Carla Ross, Director of Alumni and Affairs, for her many hours of help with business relations and advertising. Lastly we would like to thank all of the generous sponsors for their support of student research.

We are grateful to have had this opportunity to publish another successful edition of the National Foot and Ankle Review.
CONTENTS

Operative Management of Displaced Intra-articular Calcaneal Fractures. ......................... 4
Brittany Rice, B.S.; Justin Ross, B.S.

Surgical Considerations in a Hallux Abducto Valgus Revision Procedure: A Case Study. .... 12
Francesca M. Castellucci-Garza, M.S.; Arjun Sandhu, B.S.; Josh Stauffer, B.A.; Elizabeth Tronstein, MPH

Case Report: Osteopenic Marathon Runner Experiences Calcaneal Fracture After Abrupt Transition from Shod to Barefoot Running. ................................................................. 16
Alycia Chen, B.S.

Jones Fractures: A Review of the Literature ................................................................. 20
Demetrius Barnes, B.S.; Cynthia Luu, B.S.; Anna Maglunog, B.A.; Peter Pham, B.S.

Literature Review: FHL Tendinitis in Ballet Dancers .................................................. 25
Lydia Yun, B.S.; Dara Taeb, B.S.

Distraction Osteogenesis as a Treatment for Brachymetatarsia ................................ 30
David H. Tien, M.S.; Anna K. Tien, B.S.

The Efficacy of Alpha-Lipoic Acid in the Symptom Relief of Diabetic Peripheral Neuropathy ................................................................. 38
Michelle Vi Nguyen, B.S.; Francisco Mendivil-Moreno, B.S., M.P.H.; Binh Ta, B.S.

Ledderhose Syndrome and its Relationship to Dupuytren’s Disease: Leading to Additional Treatment Options ................................................................. 43
Tara L Harrington, MBA, MHA; Shanique Bingham

A Review of the Symptomatic Os Vesalianum: An Uncommon Cause of Lateral Foot Pain 49
Olubukunola Oseni-Olalemi, B.S.; Sarah Strong-Adams, B.B.A; Jessica Potter, B.S.; Tina Shahin, B.A.
Operative Management of Displaced Intra-articular Calcaneal Fractures

Brittany Rice, B.S.; Justin Ross, B.S.

INTRODUCTION
Intra-articular fractures of the calcaneus can be one of the more challenging injuries foot and ankle surgeons address. Historically, these injuries consistently correlate to short and long term sequelae and complications despite a myriad of advancements in operative approaches. Fractures of the calcaneus account for 2% of all fractures and 60% of tarsal injuries, most often from the result of direct, high energy trauma. Two classic studies report a 56-75% incidence of intra-articular fractures of the calcaneus. In the beginning of the 20th century, open operative treatment of these injuries was contraindicated. Poor results lead one prominent surgeon during that time to state, “The man who breaks his heel bone is done.” One of the early advocates for operative treatment was Böhler in 1931, but due to lack of sophisticated internal fixation techniques and hardware, complications were high. Recent advances in radiographic imaging, development of AO fixation techniques, and better understanding of calcaneal fracture pathoanatomy have lead to better results with operative treatment.

Currently, the pathomechanics involved for displaced intra-articular fractures of the calcaneus are well understood. With this injury, the loss of height through the calcaneus results in a shortened and widened heel, most commonly with varus malalignment of the tuberosity. The loss of height is observed in a decreased Böhler’s angle, whereby the normal talar declination is diminished and the talus becomes relatively more horizontal. This often leads to a secondary loss of ankle joint dorsiflexion. Furthermore, when the superolateral fragment is impacted plantarward, the thin lateral cortical wall “blow’s out” laterally, directly posterior to the crucial angle of Gissane. The anterior process will typically displace superiorly, which directly limits STJ motion via impingement of the lateral process of the talus. Understanding of the tri-dimensional architecture of the calcaneus is crucial to achieve optimal treatment results. Goals of operative treatment include restoration of the aforementioned tri-dimensional architecture of the calcaneus, optimal congruity of the STJ, optimal alignment of the hindfoot, and optimal reduction of the calcaneocuboid joint.

CLASSIFICATION & RADIOGRAPHIC CONSIDERATIONS
Radiographic assessment of intra-articular fractures of the calcaneus typically includes the four views of the foot/ankle (antero-posterior, calcaneal axial aka Harris view, lateral, and oblique views). For reconstructive purposes, contralateral limb assessment is also beneficial. Historically, the lateral view has provided the most information. When assessing the lateral plain film view, two angles are classically described, Böhler’s angle and crucial angle of Gissane. With the advent of computed tomography (CT) the ability to preoperatively plan reconstruction has lead to better results. Sanders developed the most widely utilized classification scheme which is derived from CT assessments of the posterior facet.
Figure 1(a) Lateral plain film radiograph demonstrating Böhler’s angle.
Figure 1(b) Böhler’s angle showing horizontal relationship correlated to loss of height of the calcaneus.

Figure 2(a) Harris calcaneal axial showing posterior facet congruity.
Figure 2(b) Demonstrating displacement of the posterior tuberosity with varus deviation, fibular impingement, and lateral wall blowout.

OPERATIVE TREATMENT
Currently, the operative treatment of displaced intra-articular fractures is generally indicated. A recent Cochrane review evaluated randomized and quasi-randomized controlled clinical studies comparing surgical versus conservative management for displaced intra-articular calcaneal fractures. The review included four trials (602 patients) with the majority of data coming from one large multi-center trial of 424 patients that was conducted over 15 years ago. It was stated that methodological flaws were found in all trials used leading to a high risk of bias. Nevertheless, the review concluded that currently there is insufficient evidence to support whether surgical or non-surgical treatment of calcaneal fractures is best.
When contemplating operative treatment, consideration of patient factors such as age, smoking history, comorbidities, mental capacity, gender, worker’s compensation status and the severity of the fracture must be accounted for. Multiple studies have outlined numerous complications that consistently correlate to the patient factors listed above. All of the operative techniques described in this paper have common approaches to pre-operative assessment and timing of surgery. Patients are operated on within the first therapeutic window of 12 to 24 hours, or, more commonly, surgery is delayed 10 to 14 days to allow soft tissue swelling to resolve enough for the skin to wrinkle. Another consideration to surgical approach and timing includes the development of fracture blisters. They typically develop medially but can occur anywhere on the foot. Two types are described, clear and hemorrhagic, which correlate to incomplete and complete separation of epidermis and dermis, respectively. Although one study found the fluid within fracture blisters to be sterile, surgery should be delayed until they are resolved (fully epithelialized) due to increased susceptibility to skin pathogen colonization.

Lateral Extensile Approach

Open reduction and internal fixation (ORIF) via the lateral extensile (LE) approach was initially popularized by Palmer and Letournel, but subsequently underwent multiple modifications due to consistent high rates of soft tissue complications. A landmark article by Borrelli gave insight to the unique blood supply of the lateral hindfoot. Tomesen et al. treated displaced intra-articular calcaneal fractures in 37 patients with 39 fractures using a modified Forgon and Zadravecz technique of semi-closed reduction with percutaneous screw fixation. At the 6-month follow up, the average American Orthopaedic Foot & Ankle Society (AOFAS) score was 84, and the average Maryland foot score was 86. After a minimum 2-year follow-up there were 5 cases of soft tissue complications, 1 case of calcaneal osteomyelitis, 17 cases of screw removal secondary to pain, and 2 cases that required subtalar arthrodesis. Other post operative complications that developed were 2 cases of hammertoe deformities, 1 case of complex regional pain syndrome (CRPS), and 4 cases of transient neurological disorders. Restoration of calcaneal anatomy was achieved, including calcaneal length, height, and Böhler’s angle. The comminuted fractures had the poorest results based on functional outcome, 2 of which required subtalar arthrodesis, suggesting that percutaneous fixation may not be adequate for severe fractures. One flaw of this study was that the surgeon determined which fractures to perform the technique on, specifically choosing fracture fragments that had large tuberosity and sustentaculum tali fragments, irrespective...
of any classification. This study indicates percutaneous reduction and fixation is an acceptable treatment method for intra-articular calcaneal fractures without a high degree of comminution that have tuberosity and sustentaculum fragments large enough to engage percutaneous pin placement.  

Woon et al. investigated percutaneous fixation of displaced intra-articular calcaneal fractures with the use of subtalar arthroscopy in 22 patients with Sanders type II fractures. Purported advantages of this technique include fewer incidences of wound complications and better visualization for adequate reduction of the posterior facet. Anterolateral and midlateral portals were used to obtain visualization of the posterior facet. A stab incision over the lateral aspect of the calcaneus is made to insert the periosteal-elevator to reduce the depressed superolateral fragment. The other articular fragments and malalignment were fixated with percutaneous insertion of cannulated cancellous or lag screws under fluoroscopic visualization. Results of this procedure were assessed based on radiographic and subjective outcomes using Visual Analog Score (VAS), AOFAS, and short form (SF-36; physical function) scores. Böhler’s angle was significantly corrected in all but one case and none of the cases required conversion to open surgery. At the final evaluation, 2 years post surgical date, there was reported loss of 0.5° correction of Böhler’s angle. Subjective outcome scores were measured preoperatively, and again at the 3 month, 6 month, and 2 year follow-up. Scores continued to improve at each post-operative measurement with final scores measuring 1.2, 84.2, and 77.7 in VAS, AOFAS, and SF-36 PF respectively. Reported complications included one case of a seroma and one screw removal. There were no incidences of soft tissue complications, no cases of clinical malalignment, and no cases of subtalar fusion. This study reports the benefit of subtalar arthroscopy in treating calcaneal fractures using a percutaneous approach in allowing visualization of articular surface. The authors point out the steep learning curve that is associated with this technique, as the operation time in the first case performed was 165 minutes. Additional limitations of this study include the small sample size, and the minimal objective post-operative evaluation, as the only measurement in this study was measurement of Böhler’s angle. Because this study only treated Sanders type II fractures, it is not known what role this technique plays in more severe fractures.

Dewall et al. compared percutaneous fixation with traditional ORIF using extensile lateral approach in 125 fractures. The technique used in the percutaneous group consisted of multiple small stab incisions; screw fixation and reduction using C-arm fluoroscopy with 3.5 mm and 4.5 mm fully threaded screws. The ORIF group consisted of the traditional extensile lateral approach and fixation was achieved using one third tubular plates or calcaneal plates. Average follow up was 25.7 months for the ORIF group and 21.9 months for the percutaneous group. Deep space infection occurred in 6 of 42 fractures in the ORIF group versus 5 of 83 fractures in the percutaneous group. Böhler’s angle was compared in both approaches, and improved by a mean of 22.4° in the ORIF group and 25.3° in the percutaneous group. Hardware removal occurred in 5 of the ORIF group and 10 in the percutaneous group; however the rates were not statistically significant. Calcaneal width was restored in both groups, with no difference in maintenance of the reduction at final post-operative assessment. No CT scans were taken post-operatively therefore evaluation of the articular reduction could not be attained. The results of this study indicate that extraarticular reductions are maintained and that there are decreased instances of soft tissue complications with the percutaneous technique compared to the traditional ORIF technique.

There have been many studies that assess the utility of percutaneous techniques in treating displaced intra-articular calcaneal fractures. The main outcomes are aimed to decrease the wound healing complications while maintaining reduction of the deformity. Overall, most techniques described have good results in reaching these surgical goals, however given the lack of Level I Evidence in these studies additional higher level studies should be implemented.

**Calcaneoplasty**

New techniques in treating intra-articular calcaneal fractures have been introduced using a percutaneous approach. Most recently, Biggi et al. described the use of balloon-assisted fracture augmentation with cement or calcium phosphate. This technique is also described as minimally invasive percutaneous calcaneoplasty. Using a 2cm incision on the lateral calcaneus, the articular process is visualized and temporarily fixed. A Steinman pin is used to correct any varus malalignment if present. A bone tamp is then inserted to the calcaneal body, and the balloon is inflated, followed by injection of bone cement, followed by removal of the balloon. One inherent benefit is the ability to visualize the bone cement via fluoroscopy. This allows the surgeon to see reduction, placement and amount of bone cement. Early weight-bearing was encouraged and no cast was applied post-operatively. In this small study of 11 patients with Sanders II and III fractures, no skin complications resulted, and average post operative Böhler’s angle measured 22.9°. Only one patient developed residual hindfoot pain. This new technique presents a reasonable percutaneous technique alternative to
treat intra-articular calcaneal fractures, however larger studies would be needed to support these findings.

Primary Arthrodesis
The role of primary arthrodesis in the treatment of calcaneal fractures was first mentioned in 1912 by Van Stockum, and since then has gained increasing acceptance as a treatment option for select calcaneal fractures, however the indications for the procedure remain unclear.31,32 A complication that arises with subtalar fusion is the loss of some motion in the ankle joint and midtarsal joint.33 In Schepers systematic review of primary arthrodesis for severely comminuted intra-articular fractures of the calcaneus, seven case studies and one abstract were evaluated. The findings of this study reported that the wound complication rate was 19.4%, and union was achieved in 97% among all studies. While these results indicate that primary arthrodesis is a reasonable option for surgical fixation of comminuted fractures, it was noted that a formal meta-analysis was impossible given that the current studies are too small and flawed in some way.33 Primary arthrodesis is also a viable treatment option for diabetic calcaneal fractures as reported by Facaros et al. because it provides stable reduction of the deformity and can prevent further breakdown.34 Huefner et al. performed primary subtalar arthrodesis on six patients whom the authors selected for the procedure based on the severity of comminution and/or the amount of damage to the articular cartilage of the posterior facet seen intraoperatively.32 While arthritic changes were noted on most patients on final post operative radiographs, only one developed painful talo-navicular arthritis. Five of the six patients had good to excellent results based on the AOFAS score and almost complete restoration of length, with full restoration of Böhler’s and Gissane’s angle. The calcaneal axis was completely restored in all cases. Huefner et al. compared their study to another study that performed secondary fusion due to calcaneal malalignment, and the results yielded that primary fusion had better results in terms of talo-navicular angle, ankle joint range of motion, and AOFAS score.32

Buch et al. conducted a retrospective study evaluating the results of primary subtalar arthrodesis of severely comminuted calcaneal fractures in 16 fractures. Eleven of the fractures were Sanders II or III, and the rest could not be classified. Cancellous bone graft was added to the sinus tarsi in all cases and iliac crest graft was used in some cases. Fragments were fixed with 3.5mm cortical screws and H-plates. Final results yielded a mean AOFAS score of 72.4 and radiographic union was achieved in all patients. Nine patients developed calcaneo-cuboid arthritis, and two other patients developed spontaneous calcaneo-cuboid fusion without arthritis. Four patients developed postoperative wound complications, with one patient requiring a split-thickness skin graft. Ten patients had no pain or mild pain, while the remaining patients reported moderate to severe pain. Overall restoration of the calcaneal anatomy was restored and 12 of the 16 patients were able to return to work in an average of 8.8 months.35

Primary arthrodesis is a valid surgical treatment option for more severe calcaneal fractures. The occurrence of residual arthritis in surrounding joints seems to be a common post-operative complication, however, restoration of calcaneal anatomy can be restored with this procedure and should be fully considered when treating severe calcaneal fractures.

External Fixation
The use of external fixation in treatment of intra-articular calcaneal fractures has shown positive results in the prevention of some of the major complications that arise from open surgery. Magnan et al. described the use of the Orthofix Mini Calcaneal Fixator to treat Sanders II, III, and IV fractures in 52 patients. Swelling was not considered a contraindication for the procedure and surgery was completed in a mean of 5.4 days after the injury. The fixator was left on for 8 weeks in Sanders type II fractures, and 10 weeks in Sanders type III and IV fractures. Post-removal, active and passive range of motion was continued for 2 months. Mean follow-up was 49 months and the results were assessed using the Maryland foot score, radiographs, CT scans, and the Score Analysis of Verona. 49 cases were scored good to excellent with the Maryland foot score. Böhler’s angle increased from a mean of 6.98° pre-operatively to 21.94° post operatively. Complications that occurred in this study included 3 cases of superficial pin tract infections and 3 patients with thalamic displacement due to non-compliance and early weight bearing. None of these complications required pin removal or additional surgery, respectively. Additional complications included transient local post-traumatic osteoporosis, which resolved within 4 months. Patients in this study were monitored weekly, which the authors state is important in order to reduce complications related to external fixation such as loss of reduction, screw loosening, or pin site infection. The use of external fixation for treatment of calcaneal fractures provides a shorter operating time, shorter hospital stay, and reduced risk to surgical exposure compared to open fixation. These results support the idea that successful clinical outcomes can be attained without obtaining anatomical reduction of subtalar articular fragments. Results of this study are consistent with results that follow early postoperative mobilization and restoration of Böhler’s angle. Overall it was shown that this technique is a reliable method for stable reconstruction of intra-articular calcaneal fractures.36
Triangular tube-to-bar external fixation has also been described to treat displaced intra-articular calcaneal fractures. Roukis et al.37 surgically treated 66 fractures using this technique and evaluated each patient one year after surgery. Outcomes were assessed using radiographic analysis and the “Calcaneal Fracture Scoring System.” The severity of subtalar joint osteoarthrosis was also staged at the final evaluation using the Paley and Hall four-stage system. Patients remained non-weightbearing until radiographic evidence of consolidation was noted and the external fixator was removed after 8 weeks. Outcomes were good, very good, or excellent in 82% of the fractures. 74% of the fractures showed no or mild subtalar joint osteoarthrosis at final evaluation. All fractures reached consolidation. Complications in this series included Schanz screw site infection in 11.3%, CRPS in 4.8%, neuroma development in 3.2%, and tarsal tunnel syndrome in 1.8%. One patient required a subtalar joint arthrodesis and two patients required further modification of the fixator during the treatment period. The following radiographic measurements were obtained: Böhler’s angle, Gissane’s angle, talo-calcaneal angle, tuber height, calcaneal length, calcaneal width, and hindfoot alignment. All the aforementioned angles were corrected into a normal range for most patients without the use of bone grafting or open techniques. It was mentioned in this study that the 18% of patients who reported poor outcomes had a joint-type depression fracture, a comminuted fracture, or poly-trauma suggesting that this technique may not be the best option for severe fractures. The arthrodiasis between the ankle and subtalar that is created by this device may also aid in preventing the development of degenerative changes to the those joints over time, although this was not directly studied in this trial.37

Talarico et al.38 looked at the use of high tensioned wires with an external fixation frame with 2 tibial rings connected to a foot plate in treating displaced intra-articular calcaneal fractures. The authors highlighted that one of the problems seen with prolonged weightbearing is residual hindfoot pain and hypothesized that overall outcomes could be improved using external fixiation with early weightbearing. This study included 23 patients with 25 intra-articular calcaneal fractures classified as a Sanders II, III, or IV. A two year follow up was required and final assessments were based on radiographic evaluation, Maryland foot score, Paley’s classification, and pain and range of motion of the rearfoot joints. Patients were allowed to ambulate on post-operative day 1 with crutches or a walker. A bone stimulator was dispensed on the first visit and the frame was removed after evidence of fracture consolidation (average of 6.6 weeks). Final follow-up revealed 32% excellent, 60% good, and 8% fair based on the Maryland foot score. None of the patients required additional surgeries and no deep infections were seen. Common complications noted were mild pain, and less commonly, complications of persistent pain and nerve compression. All of the patients maintained >50% of subtalar joint range of motion compared to the contralateral foot. The advantage of the external fixator, as mentioned by the authors, is stabilization of the manually reduced fracture fragments. Additionally, distraction of the subtalar joint was enabled to help prevent and/or delay progression of degenerative changes.39 Although there were no open or severely comminuted fractures in this study, the authors state that this technique can be applied to nearly every instance of intra-articular calcaneal fractures when surgery is indicated.38 Further studies should be conducted to evaluate its use in severe calcaneal fractures.

Delta-frame external fixator constructs are discussed in the literature to surgically fix displaced intra-articular calcaneal fractures using a technique called ligamentotaxis. Ligamentotaxis is defined as the indirect realigning of fracture fragments caused by tension applied to the fractures by the attached ligaments.40 By using an external fixator to manipulate the subtalar joint in calcaneal fractures, the height of the posterior talocalcaneal joint can be restored and the varus/valgus malalignment and width of the calcaneal tuberosity can be reduced.40

Kissel et al.41 postulated that restoration of the comminuted subtalar joint depression and calcaneal alignment can be attained utilizing this ligamentotaxis. The authors conducted a retrospective cohort study with 10 patients with a Sanders II, III or IV fracture, excluding polytrauma patients. Patients were non-weightbearing for the first 6 weeks, and upon removal of the fixator, remained non weightbearing for an additional 6 weeks in a removable cast. Final evaluation was completed one year after the date of surgery. Based on the Maryland foot score, 9 patients scored good to excellent, and 1 patient scored fair. Calcaneal height, width, and length as well as normal ranges for Böhler’s and Gissane’s angle were restored postoperatively in all patients. One of the advantages of this technique is that the procedure can be done entirely percutaneously, avoiding the complications that accompany large surgical incisions. Other advantages include shortened operation time and distraction of joints in all 3 planes. One documented disadvantage is the inability of the pin used in this construct to engage small calcaneal tuberosity fragments, which are commonly seen in severely comminuted fractures.41

In summary, external fixation is shown to be a reasonable option in treating most types of intra-articular calcaneal fractures, with specific constructs providing additional purported benefits as mentioned in the above
studies. External fixators should be considered when treating calcaneal fractures in patients with comorbidities that affect their ability to heal, such as diabetes, peripheral vascular disease, or a history of smoking. Benefits of external fixation mentioned by Sagray et al., include reduction and stability of the fracture, supplementing internal fixation if inserted, and off-loading and protection of the soft tissue envelope.42

DISCUSSION
While calcaneal fractures represent a small percentage of all fractures, the complexity of the injury is a surgical challenge for foot and ankle surgeons. Many surgical techniques have been developed and studied to treat displaced intra-articular calcaneal fractures, however there remains no superior method over another. Despite numerous clinical trials that have been implemented, it is difficult to compare the results of each study due to the inconsistencies between each one. As seen in this literature review, patient inclusion/exclusion factors, follow-up time, and final evaluation methods are just some of the widely varied factors between each study, making it difficult to establish comprehensive comparisons. Although various surgical advances have been made over time, post-traumatic arthritis and infection remain some of the most common complications, highlighting the complexity of this fracture type. Continued research should be done to establish standards of treatment for different stages of displaced intra-articular calcaneal fractures.

REFERENCES
INTRODUCTION
First metatarsophalangeal (MTP) joint pathology, such as hallux abducto valgus (HAV), is one of the most common forefoot pathologies encountered by foot and ankle surgeons. Hallux abducto valgus is characterized by a lateral deviation of the hallux and medial deviation of the first metatarsal. The condition also consists of a varying degree of rotation in the frontal plane. "Pooled prevalence estimates" suggest a 23% prevalence of HAV in adults aged 18-65 years and a 35.7% prevalence in those over 65 years of age. There is a wide clinical spectrum when patients present with a bunion deformity, from asymptomatic to painful and functionally disabling. It is important to understand the patient’s history, physical and radiographic examination findings before deciding on a surgical plan best suited for the specific patient.

In the current case report we examine a patient who presented after a failed HAV surgery. Pre-operative factors, fundamental surgical guidelines, failure of the first surgery and what was done to correct the failure will be discussed.

CASE REPORT
This case presents a 52 year old female with a complaint of recurrence of HAV with a painful bunion deformity and second digit hammertoe of her left foot. The patient stated that approximately one year ago she had surgical correction of the aforementioned deformities, however they have recurred. The patient related that she had even more discomfort at the time of the visit as compared to her pre-surgical state.

Medical records showed that an Austin-Akin bunionectomy and arthroplasty of the second digit were performed. Clinical exam and radiographs were performed at the time of the visit. The clinical exam revealed tracking of the first MTP joint. Range of motion testing was negative for pain or crepitis at the first MTP joint and adequate range of motion of the joint was observed. Hypermobility of the first ray was noted. The patient complained of pain upon palpation of the medial aspect of the first metatarsal head. Radiographs showed an intermetatarsal angle (IMA) of 19 degrees, a functional proximal articular set angle (PASA) of 16 degrees and an overcorrection of the distal articular set angle (DASA) of 6 degrees. The second digit hammertoe was found to be non-reducible. The corrective revision procedures performed included a Lapidus arthrodesis, Reverdin-Green bunionectomy, first MTP joint soft tissue rebalancing including fibular sesamoidectomy and second digit arthrodesis.

DISCUSSION
Hallux abducto valgus is an acquired and progressive deformity that results in abnormal mechanics occurring at the first MTP joint during gait. It is imperative that the practitioner evaluate the causative factors along with the pathologic manifestations of the condition.

Primary etiological factors include: abnormal biomechanics of the first ray or first MTP joint, metatarsus primus elevatus, abnormal pronation with an unstable first ray, an abnormal IMA, and a long first ray. Secondary causes may be due to: trauma, neuromuscular disorders, arthritides, congenital abnormalities or iatrogenically induced. With the many potential causative factors of HAV, it is important to take a careful history, thorough lower extremity physical exam and obtain the necessary radiographic parameters in order to decide on the most appropriate treatment plan for an individual patient. There is not necessarily one “correct” surgical plan that all foot surgeons would arrive at given a certain patient, however there are fundamental considerations that must be taken into account.

Fundamental surgical guidelines for HAV begin with establishing a congruous first MTP joint. Proper alignment of the head of the first metatarsal and base of the proximal phalanx will allow the first MTP joint to gain the necessary degrees of dorsiflexion and plantarflexion during gait. This proper range of motion will prevent pathological articulation which can
lead to degenerative joint disease and osteoarthritis. Furthermore, maintaining the first MTP joint range of motion is important in preventing recurrence of symptoms, and has been correlated to patient satisfaction.\(^5\) In a cadaveric study it was shown that immediately after HAV surgery dorsiflexion on average decreases 22.6 degrees (statistically significant compared to pre-operative measures) with plantarflexion decreasing 0.6 degrees (not statistically significant).\(^3\) Without sufficient dorsiflexion, jamming of the first MTP joint occurs and can result in hallux limitus, pain, decreased overall patient satisfaction and other associated pathologies.

In addition, restoring the weight bearing function of the first ray is essential to the success of HAV surgery. “The first ray…is arguably the most dominant mechanical structure of the forefoot. As a result, its proper function is critical.”\(^6\) Without this key function a long list of pathologies can develop, “if the first ray cannot support the load, the medial column can fail as a rigid lever with subsequent arch collapse and load shift laterally to the lesser metatarsals.”\(^7\) Overloading the lesser metatarsals may contribute to “second metatarsophalangeal synovitis, interdigital neuromas, metatarsalgia, and stress fractures”\(^7\), along with hallux limitus and degenerative arthritis.

**SURGICAL FAILURE**

When considering HAV, the surgeon must be careful to choose the correct surgical procedure based on the history related by the patient, physical examination and radiographic findings. In this case, the previous surgeon chose to perform an Akin procedure despite the fact that an Akin is indicated where there is an abnormal interphalangeal angle or distal articular set angle.\(^8\) Along with this, abnormalities in the IMA should be corrected concomitantly to restore functionality of the joint. The main problem with the Akin procedure is that it fails to re-align the joint and restore normal function. This is why the Akin is rarely used alone, and most often paired with an Austin procedure that attempts to re-align the tendons.\(^9\) While the Akin-Austin combination provides an aesthetically acceptable solution, it fails to correct HAV deformities that are considered severe due to the large IMA.

In this particular case, the IMA of 19 degrees displayed by the patient following the initial Austin-Akin procedure demonstrates a lack of appreciation for this significant angle by the previous surgeon (Figure 1). The IMA had not been appropriately corrected with the Austin osteotomy alone, and there was an overcorrection of the distal articular set angle by approximately 6 degrees. While the Austin osteotomy is indicated in patients with a mild IMA deformity, it should not be used in patients with an IMA over 16 degrees.\(^10\) Taking into account that the patient presented with an IMA of 19 degrees, the Austin osteotomy alone was not sufficient to correct the IMA (assuming the deformity had not changed since the first surgery) and is suspected to have led to the patient’s recurrence of HAV. Often soft tissue rebalancing is employed with the Austin technique, which was not done adequately in this case.\(^11\) A lateral soft tissue release would have greatly increased the chances of success when using an isolated Austin for correction of the IMA.\(^12\) This case warranted a more proximal procedure due to the IMA of 19 degrees and first ray hypermobility.

When considering first ray hypermobility it is important to realize that it may not necessarily be the cause of the hallux valgus deformity, but it represents a progression of the deformity.\(^13\) The first tarsometatarsal joint is responsible for 41-57\% of total medial column motion.\(^14\) Failure to address the problem of hypermobility often results in second MTP joint pathologies such as metatarsalgia, capsulitis, or hyperkeratotic lesion formation.\(^15\) Regardless of the etiology of first ray hypermobility, a more proximal procedure must be employed in order to help prevent problems associated with the second MTP joint and help close the IMA.

The final problem with this case was the arthroplasty of the 2nd digit. The arthroplasty failed to create a stabilizing force against the lateral movement of the hallux. Together, first ray hypermobility and the instability of the 2nd digit allowed for further progression of the bunion deformity in the transverse plane. Ultimately, failure to restore normal structure led to abnormal function and further progression of the deformity.

**SURGICAL CORRECTION**

Utilization of a proximal procedure to help correct the IMA was a necessity in this case (Figure 2). When presented with first ray hypermobility, the procedure that is most often used with the best result would be the Lapidus. This is especially true when considering recurrent HAV after failed surgical treatment, where a Lapidus can help provide functional stabilization by markedly decreasing transverse and sagittal plane movement.\(^16\) Research suggests that a Lapidus arthrodesis may result in a decrease in first ray motion by 50\%.\(^14\) Altogether, this procedure not only closes the IMA sufficiently, but stabilizes the first ray. This provides a stable platform from which propulsion can take place while preventing second MTP joint pathologies. However, such a significant proximal procedure may convert a normal functional PASA to dysfunctional, thus warranting a distal procedure as well. The distal procedure would need to adequately re-position the articular cartilage and a procedure such as the Reverdin-Green is perfect for restoring functionality to the PASA.\(^17\)
Not only does this procedure help correct the proximal articular set angle, but can reduce any IMA abnormalities leftover from the Lapidus procedure.

One could speculate that the Austin-Akin procedure could have re-engaged the windlass mechanism by aligning the pull of the hallux perpendicular to the MTPJ. However, this was not the case not only due to a high IMA, but failure to adequately address the soft tissue deformities. With a lateral soft tissue release, medial capsulorrhaphy and a fibular sesamoidectomy, one can greatly decrease the rate of reoccurrence in surgical HAV patients. With these techniques, the retrograde buckling force can be decreased adequately enough to prevent further progression of the HAV deformity. Progression of a bunion deformity is not only due to soft tissue imbalances at the first MTP joint, but also instability of the second digit plays a great role. Failure of the second digit to act as a lateral buttress is another problem present in this case. Even though the arthroplasty of the 2nd digit corrected the hammertoe deformity, it left little to no resistance against the lateral deforming force of the hallux. While it may not seem that a 2nd digital arthrodesis would provide enough resistance to the lateral deforming force of the hallux, it at reinforces the primary goal of the whole surgical treatment. Altogether, a surgical procedure consisting of a Lapidus, Reverdin-Green, soft tissue lateral release with fibular sesamoidectomy, and a 2nd digital arthrodesis was the treatment of choice for this revision.

**CONCLUSION**

Podiatrists share a paradigm – a constantly evolving stance on what is the respective “correct” treatment. Failure to abide by this paradigm often results in outcomes that could have been avoided in the first place. In this case, failure to recognize a large IM angle, coupled with over-correction of the distal articular set angle, along with a lack of soft tissue correction and a 2nd digit arthroplasty resulted in increased pain for the patient. The choice of inappropriate procedures resulted in increased pain for the patient. Podiatrists have a responsibility to do no harm, and in this case, the initial procedures were worse than continuing conservative treatment. This case resulted in additional surgery, increased medical costs, and inconvenience for the patient. Podiatrists have a responsibility to patients to properly assess their patients’ conditions, and to choose appropriate interventions that address the pathology. It is critical to account for a patient’s history, biomechanical and physical examination finding in addition to assessing radiographs prior to procedure selection. In this case, a Lapidus, Reverdin-Green, soft tissue lateral release with fibular sesamoidectomy, and a 2nd digital arthrodesis would have been better choices for the patient.
REFERENCES


Case Report: Osteopenic marathon runner experiences calcaneal fracture after abrupt transition from shod to barefoot running

Alycia Chen, B.S.

ABSTRACT

Minimalistic running refers to running shoes with thin soles, to mimic barefoot running, yet protect against direct trauma to the plantar surfaces of the feet. Advocates claim that minimalist shoe gear returns the runner to a more natural gait, thus reducing running injuries. It is hypothesized that by landing on the mid-foot rather than a heel-first strike, there is a reduced risk of injury due to decreased transient ground reaction force experienced at initial contact. Modern day footwear is characterized by an elevated heel, midsole cushioning and motion control. Though there have been many advancements in shoegear, there is insufficient evidence to support injury prevention in shod running. To date, there is a lack of peer reviewed supporting evidence in support of shod running and a significant reduction in injury rate. Additionally research has also not supported the claim that barefoot running prevents or lessens the risk of injury. In this case study we examine a newly converted barefoot runner with osteopenia who switched from shod to minimalistic shoe gear, while maintaining her heel-strike running pattern.

CASE REPORT

This case presents a 35 year old female who was training for a marathon when she developed pain and swelling in her right foot. The patient was running 30 miles per week in running shoes, and before injuring herself switched to minimalist shoes with no change in stride. The patient complained of pain located at the right medial and lateral ankle with ambulation. Upon physical examination the patient was found to have soreness with compression of the right heel. Moderate edema was noted at the posterior and inferior heel, with erythema but no ecchymosis. The patient was antalgic while walking with heel contact, but had decreased pain while walking on her toes. Ankle and subtalar joint range of motion were within normal limits, and ankle strength was good in all four directions. Initial x-rays were read as negative, but MRI relevant findings included a calcaneal stress fracture. Diagnosis of pre-menopausal osteopenia was made by Dual-energy X-ray Absorptiometry (DEXA), which was found to be within 2 standard deviations of normal bone mass density. Fracture Risk Assessment Tool (FRAX) score was calculated, which determined a low fracture risk and was below threshold for pharmacologic treatment. Secondary causes of osteopenia were ruled out by performing a complete blood count (CBC), serum chemistry levels (which included levels of serum calcium and phosphate), serum iron and ferritin levels, liver function tests, thyroid stimulating hormone (TSH) level, and 25-hydroxyvitamin D levels, all of which showed no abnormalities. She was placed non-weightbearing with crutches in a removable anklider boot. She was then started on an Exogen bone stimulator for 9 weeks and at the time of follow-up soreness was nonexistent on compression of her heel. Patient was weaned off the crutches at 2 months, and began a jogging program by 6 months. Custom made functional foot orthoses helped with shifting the weight from the painful heel onto the non-painful arch and controlled her excessive pronation with shod running shoes; she is now able to comfortably run 3-4 miles every other day without calcaneal fracture reoccurrence.

DISCUSSION

Overuse injuries of the LE

Most running injuries are due to overuse, and 70-80% of the time are located from the knee downward. It has been shown that up to 22% of overuse running injuries are in the feet. The cause of running injuries varies from metabolic abnormalities such as anemia, amenorrhea, hypothermia and hyperthermia. The most significant factors related to running injuries were related to previous injury, lack of running experience, running competitively and excessive running distance with increased duration, frequency, or change
in specific form of training (as seen with this patient). Musculoskeletal imbalances are thought to also facilitate overuse injuries, therefore gradual adaptations by the intrinsic and extrinsic musculature as well as osseous adaptations and connective tissue conditioning are important to avoid injury and transition properly to minimalistic running.\(^1,4\) Salzler et al. reported 10 experienced runners who presented with stress fractures while transitioning from habitual shod running to minimalistic shoes; this included 8 metatarsal stress fractures, one calcaneal stress fracture and one plantar fascial rupture.\(^1\) The metatarsal stress fracture suggests increased microtrauma to the metatarsals while running with a forefoot or midfoot strike. The calcaneal stress fracture was most likely caused by continual heel-strike in minimalistic shoes as well as the increased forces transmitted through the calcaneus from the pull of the gastroc-soleus; which is most likely what happened to the patient in the current case study.

**Fractures with osteopenia**

Suddenly changing to barefoot (BF) running may have altered the dynamics in the compression forces of running, enough to cause a fracture in this osteopenic patient. A study by Marx et al., examined a study linking osteopenia to stress fractures.\(^7\) In their retrospective, controlled, cross-sectional study, they examined athletic females under the age of 40 that had sustained stress fractures of cancellous bone. There was a strong correlation between osteopenia and cancellous stress fractures when observing those that already had stress fractures while having a lower bone density index. These findings are consistent with this case study, but what is interesting is the mechanistic difference in forces from changing training techniques from shod to BF running.

**Foot strike alteration**

In habitually long distance shod runners, 75-88\% have been shown to prefer rearfoot strike.\(^6,10\) This rearfoot strike pattern in modern running shoes is likely facilitated by the elevated and cushioned heel, which is found to decrease dorsiflexion and increase plantarflexion by 5 degrees at impact due to the added 1 to 3 cm built into the shoe beneath the heel.\(^2,11\)

The most observable and significant change with barefoot running is the change in strike pattern, which includes a forefoot strike pattern with increased plantarflexion.\(^4\) This may be due to the inability to tolerate the lack of adequate heel cushioning and pain from repetitive trauma beneath the calcaneus.\(^11,12\) A study by Divert et al. demonstrated 9 of 12 rearfoot strike shod runners tend to switch to a midfoot strike while barefoot.\(^13\)

**Collision forces during foot strike**

A forefoot strike pattern has been shown to lessen passive ground reaction forces versus shod running. This is possibly because barefoot runners tend to avoid heel contact and land more on the forefoot.\(^1,14-16\) This decreased impact peak is due in part to an increase in plantarflexion of the foot at impact and heel control by the Achilles, which decreases the effective mass of the lower extremity that collides with the ground.\(^2,14\) In contrast, rearfoot strikers have the most impact below the ankle, increasing the effective mass of the body that collides with the ground.\(^2\) This increased impact force is thought to be responsible for stress fractures in running related injuries.\(^4,17,18\)

Furthermore, maintaining the same heel strike pattern in minimalist shoes significantly increased the maximal loading rate.\(^3\) Liberman et al. found that both rearfoot strikers, whether habitually shod or barefoot, had seven times the loading rate when compared to barefoot forefoot strikers.\(^2\) Modern shoes have the advantage of having elastic materials at the heel which absorbs these collision forces during foot strike and decreases the impact of a repetitive heel strike pattern, which enables the force to spread over a longer period of time and thus reduces stresses on the foot. In contrast, barefoot rearfoot strikers’ lack of external protection and minimal shock reduction have high loading rates and magnitude collision forces repetitively travelling up the body. These are considered important factors that may play a role in stress fractures from running related injuries.\(^17,19-21\) De Clercq et al. also demonstrated that barefoot heel strikers had a 60.5\% heel pad deformation while 35.5\% in shod running, which decreased its functional role in absorptive capacity and its ability to protect the calcaneus.\(^21\)

**Gastroc-soleus activation**

Electromyography signals of the gastrocnemius muscle showed significant differences in barefoot versus shod landing. Barefoot runners’ forefoot landing has demonstrated increased load intensity by the gastrocnemius activity in both the preactivation and stance phases of gait. This increased gastrocnemius activity is believed to reduce impact peak and cushion impact through the leg muscles.\(^3,14,23-25\) In a study by Cronin et al., increased medial gastrocnemius and soleus muscle fascicle activity was found in habitual shod runners that maintained heel-strike while running barefoot by 1.7-4\%.\(^26\) Without slowly transitioning to load intensity, barefoot running cause injuries from excessive eccentric contraction after foot landing, including tendonitis of the Achilles or a calcaneal stress fracture as depicted in this patient.
CONCLUSION

Running related injuries in the lower extremity are extremely common and are most frequently due to overuse, though their diverse nature requires the podiatrist to look at the running behavior, genetics, along with the environment including the patient’s shoe gear.

Though the connection between shod running and injury prevention remains unclear, an osteopenic patient would benefit from the use of orthotic devices, due to the cushioned insole and the ability to mitigate increased impact forces during foot strike. Biomechanically, the most obvious difference between habitual shod and barefoot runners is their landing pattern, demonstrating forefoot striking in shod versus heel strike in barefoot runners.3 Though minimalist runners may gain more shock absorption with forefoot strike, continuing rearfoot strike in minimalist running shoes negates this advantage as demonstrated by this case study. In this case report, the patient was a habitual shod runner that abruptly converted to minimalist running yet continued her heel strike pattern. This unnatural barefoot gait pattern increased the heel impact forces, which predisposed her to injury. Barefoot running has been found to cause increased pre-activation of the gastroc-soleus complex during barefoot running with both forefoot and rearfoot strikers.3 We can speculate that all of these factors led to her calcaneal injury due in part to the lack of tissue adaptation at her calcaneus, with increased pull by the gastroc-soleus while wearing minimalist running shoes, and increased loading rate. All of these aforementioned factors are important to considered while determining the cause of a running injury, and emphasizes the need for the habitual shod runner to transition slowly to a more forefoot strike pattern while wearing minimalist shoes.3,4 No study has demonstrated the safest method for transitioning into a minimalist running program, but Robbins and Gouw suggest habitual shod runners require 6 weeks of adaptation for plantar skin and musculature, with daily barefoot running to reach and maintain adaptation.2,3

REFERENCES

INTRODUCTION
Approximately 45-70% of metatarsal fractures in the foot occur at the fifth metatarsal. These fractures, especially the Jones fractures, can be severely debilitating for patients, specifically for our athletic population. The Jones fracture was originally described in 1902 by Sir Robert Jones, a surgeon of English descent, who sustained the injury while dancing around a military pole. Jones described the injury as a “cross-breaking strain directed anteriorly to the metatarsal base and caused by body pressure on an inverted foot while the heel was raised”. Contemporary literature defines a Jones fracture as an acute fracture of the fifth metatarsal at the junction between the proximal diaphysis and metaphysis of the fifth metatarsal without distal extension beyond the fourth to fifth intermetatarsal articulation.

This review aims to discuss the unique shape and precarious blood supply of the proximal fifth metatarsal, conservative treatment regimens, surgical indications, and current techniques for surgical management and fixation.

ANATOMY
Dissection of the foot reveals that the fifth metatarsal articulates with the cuboid at its base and medially with the 4th metatarsal base.2 It is oriented in a dorsalplantar direction with a posterior lateral projection which is characterized as a tubercle or more commonly referred to as the styloid process.5 One of the major everters of the foot, the peroneus brevis, inserts here and the peroneus longus travels through the distal portion of the cubostyloid groove on the plantar surface. There is a series of ligaments that attach to fifth metatarsal which include the interosseous metatarsal ligament (M4-M5), as well as the dorsal and plantar intermetatarsal ligament.

The fifth metatarsal is unique in regard to its shape and blood supply. The fifth metatarsal gets its nutrient artery from the medial surface of the diaphysis and from arteries on the plantar aspect of the proximal diaphysis.5 In addition there is arterial supply that flows from the dorsal and medial surfaces. Metaphyseal blood to the fifth metatarsal is derived heavily from surrounding soft tissue in conjunction with the head and base of the metatarsal. The epiphyseal blood supply is less consistent as it has two to three branches that enter from the medial and lateral aspect, with the lateral epiphyseal vessel missing at times.5 The lymphatic system of the fifth metatarsal is connected to the lateral draining system which flows to the popliteal node.

There are several classification systems that have been designated to the fifth metatarsal. The most commonly used classifications are Stewarts and Torg (Figure 1). Stewarts classification refers to the Jones fracture as a type one fracture, and describes it as a transverse fracture at the diaphyseal-metaphyseal junction of proximal portion of the fifth metatarsal.7

ETIOLOGY
Fractures of the fifth metatarsal can occur at various points along the metatarsal. The true Jones fracture is described as a transverse fracture of the diaphyseal/metaphyseal junction near the base of the fifth metatarsal.7 It is believed this injury occurs as the result of a sudden thrust or force which produces an adduction force to the forefoot analogous with plantarflexion along the lateral border of the foot while the heel is raised.8 It has been suggested that athletes are at high risk for these types of equino varus indirect force injuries due to the repetitive cutting and pivoting motions that are required for sports activities.5 Persons with intrinsic hindfoot varus, metatarsus adductus, or transverse plane forefoot pathology may also be more susceptible to these injuries due to increased forces on the lateral column of the foot.9
TORG CLASSIFICATION | RADIOGRAPHIC APPEARANCE
---|---
Type I | No intramedullary sclerosis
| Fracture line with sharp margins and no widening
| Minimal cortical hypertrophy
| Minimal evidence of periosteal reaction to chronic stress
Type II, delayed | Fracture line that involves both cortices with associated periosteal bone union
| Widened fracture line with adjacent radiolucency related to bone resorption
| Evidence of intramedullary sclerosis
Type III, nonunion | Wide fracture line
| Periosteal new bone and radiolucency
| Complete obliteration of the medullary canal at the fracture site by sclerotic bone

**Figure 1. Torg's Classification System for Fractures of the Proximal Fifth Metatarsal Within 1.5 cm of the Tuberosity**

**IMAGING**
Clinically, knowing the mechanism and using the Ottawa rules can help contribute to make a diagnosis of a Jones fracture. Plain radiographs are the mainstay for correctly diagnosing a Jones fracture. Diagnosis should be made with at least three views. Jones fractures should be differentiated from avulsion, tuberosity, intraarticular, stress and crush fractures. An acute fracture is seen as a linear break through the metatarsal. Torg, et al came up with a classification scheme for jones fracture based on plain film (refer to Figure 1). Other imaging modalities may be more sensitive including MRI, ultrasound, and CT scan.

**NON-OPERATIVE TREATMENT**
After the initial foot injury, it is important for the patient to rest, ice, use compression and elevate (“R.I.C.E”) his or her foot. Treatment will depend on the type and location of the fracture. Also, each patient is different and ultimately, they should decide what therapy is necessary to meet their lifestyle. Injury to the 5th metatarsal base may be problematic due to its poor vascularity and poor osteogenic capability, sometimes referred to as the “watershed area.” In a study by Torg et al. in 1984, Torg found that 93% of acute Jones fractures that were treated with a non-weight bearing cast for eight weeks healed. More recently, Fernandez et al showed that non-unions may occur in up to 50% of non-operative patients. If a non-unon does occur, an additional conservative measure such as a bone stimulator or ultrasound may be indicated.

If the fracture is not significantly displaced, a Jones fracture can be treated conservatively using either a cast, splint, or CAM walker for 6-8 weeks. Following the non-weightbearing period, patients are allowed to weight bear as tolerated and start mobilization to get blood perfusion to the area. In a study by Peter Vorlaet et al., the most significant predictor of poor functional outcome was longer periods of non-weightbearing. Once conservative methods have been exhausted, surgical correction may be deemed necessary.

**OPERATIVE TREATMENT**

**Surgical Indications**
General consensus regarding indications for surgical fixation of Jones fractures include: acute fractures in elite athletes, open fractures, and delayed or non-unions. In a prospective, randomized trial by Malogne et al., they found a 44% incidence of non-union, delayed union, and refractures in nonoperative treatment of acute Jones fractures with cast immobilization. Comparatively, early screw fixation with a 4.5mm malleolar screw resulted in a clinical union 7.6 weeks earlier than with cast immobilization as well as a 7.7 week earlier return to sport. Portland et al. found that operative treatment resulted in a more predictable union rate as well as an earlier return to weightbearing. Portland achieved a 100% union rate using intramedullary fixation in 22 patients. Of note, Portland et al. recommend immediate intramedullary fixation for Jones' fractures and acute Torg type I and II fractures in both non-athletes and athletes. Tzaknis et al. recommend surgical fixation in patients whose athletic or physical performance requires return to pre-injury levels of activity earlier than nonoperative treatment and noncompliance with immobilization.
**Internal Fixation**

Several constructs for fixation of Jones fractures have been studied including low profile plates, intramedullary screws, mini-fragment screws, intraosseous wiring, and hook plates. However, intramedullary screw fixation is the most common and is considered the operative treatment of choice for Jones fractures. Screw selection remains controversial in literature, however, the most common are 4.5mm to 6.5mm partially threaded screws.

Shah et al. demonstrated that a 4.5 mm screw diameter is adequate for fixation, with no statistical significance to illustrate that a 5.5 mm screw diameter improves 3-point bending failure load strength. Porter et al. also found 100% union, high patient satisfaction rates, and no refractures after using 4.5 mm cannulated screws in 23 athletes. Kelly et al. noted that the fifth metatarsal can accommodate a 6.5 mm screw, which affords greater pull-out strength than smaller-diameter screws, but not greater fracture stiffness. In addition, they demonstrated that a larger diameter screw can be more effective in operative management given the indirect mechanism of the injury. Horst et al. found no significant difference in the ability to resist torsion either with 6.5 mm or 5.0 mm screw fixation. However, Horst et al. found that a longer 5.0 mm screw is needed to purchase the fifth metatarsal head and neck to provide stability.

In regard to screw length, a shorter screw is appropriate as long as threads crossing the fracture site gain circumferential cortical purchase, which will provide the most biomechanical strength with least chance for nonunion. Ebraheim et al. reviewed the osteology of the fifth metatarsal and noted that it is curved or “bowed” with greater cortical density medial-lateral compared to dorsal-plantar. A longer screw is not necessary and may be harmful to the normally curved metatarsal, contributing to possible nonunion or refracture. Therefore, it is essential to use the largest screw diameter that the intramedullary canal of the fifth metatarsal can accommodate while simultaneously ensuring the threads just past the fracture site.

Intraoperatively, the medullary canal should be measured and the appropriate size screw diameter determined. Typically, an incision is made proximal to the fifth metatarsal tuberosity between the tendon of peroneus brevis and plantar fascia. After the tip of the base of the fifth metatarsal is identified, an appropriate guide wire should be placed in the dorsomedial aspect of the tuberosity. Confirmation of the wire into the medullary canal should be made using a C-arm and an appropriate length screw should be measured. The proximal fragment should be overdrilled if using lag technique to allow for compression and a countersink reamer should be used to avoid prominence of the screw head. An appropriate length screw should be placed and all threads should be distal to the fracture site and there should be no penetration of the distal cortex.

Post-operative management entails keeping patients non-weightbearing for the first 2 days following surgery. Elevation, cryotherapy, and oral NSAIDs are also recommended post-operatively. Non-weight-bearing range of motion exercises are started as soon as the patient is able to tolerate them. It is recommended that the patient is partial weight-bearing with crutches for four weeks. During the seventh and tenth week, after radiological fracture healing is shown, a gradual transition to activities may commence with the athlete allowed to start jogging. The athlete may return to pre-injury level sports activity by twelve weeks post-operatively.

Surgical complications include injury to the sural nerve as it lies directly over the peroneus brevis, irritation from a prominent screw head, refracture, and delayed or non-union. Refracture and incomplete union are most likely a result of the screw threads having not crossed the fracture site completely or the screw not obtaining purchase distally. In addition, it is possible that the length of the screw is too long that the curved metatarsal straightens causing distraction of the lateral cortex.

**EXTERNAL FIXATION**

The use of external fixation has become another possible option for the treatment of Jones fractures. Although the outcomes are promising, current literature only contains small case studies to validate the effectiveness of the external fixator for Jones fractures. Yu and Shook first described the use of unilateral external fixation for a Jones fracture in 1997. They demonstrated an Iliazarov mini rail external fixator allows for controlled axial compression and dynamization across the fracture site while allowing for early weight bearing. This procedure is done under fluoroscopy in order to decrease amount of dissection to preserve blood supply.

The technique entails placing one or two pins perpendicular to long axis of the bone, ensuring they go through two cortices. Fishco et al. recommend using 0.045 k-wires as guide holes to allow for alignment. The pins are inserted with one at the base of the fifth metatarsal proximal to fracture line, and two distal to the fracture line. Pins are inserted in a lateral to medial or from dorsal to plantar fashion. Once the device is placed, it is then tightened for compression across the fracture site. In a study by Lombardi et al., 9 out of 10 patients achieved union and one nonunion was asymptomatic.

Post-operatively, the patient is to remain partial...
weight bearing with crutches for the first two weeks, with gradual transition to weight-bearing as tolerated. Fixators are left on for 6-8 weeks until radiographic healing is noted. Daily pin care with peroxide and antibiotic ointment is advised. Once the device is removed, patients are placed in a short leg cast for an additional two weeks before returning to normal shoegear. Lombardi et al. showed that patients were able to return to pre injury activity as early as 6.7 weeks post-operative with the mean being 9 weeks. The use of an external fixator is contraindicated if there is significant malalignment, displacement or comminution of the Jones fracture. The primary complication is pin tract infection and pain at the pin sites.

CONCLUSION
The Jones fracture, located at the metaphyseal-diaphyseal junction of the fifth metatarsal, may pose a difficult treatment dilemma for our athletic patient population. The challenge for some patients to heal Jones fractures may be due to the unique anatomy and the precarious blood supply of the proximal fifth metatarsal. Non-surgical treatment of acute fractures have many potential adverse effects, with prolonged immobilization of the soft tissue structures of the ankle and disuse osteoporosis of the lower extremity. The size and type of operative fixation for Jones fractures has also been a controversial topic, with intramedullary screw fixation continuing to be the mainstay of treatment for foot and ankle surgeons. Although external fixation has been suggested as a viable option, only case studies with small patient populations have been done. Further research is necessary to determine which surgical option: internal versus external fixation yields more optimal results. We suggest future studies with an increased number of participants, comparisons between non-operative treatment versus internal fixation with intramedullary screw versus external fixation, and longer follow-up periods.

REFERENCES
Literature Review: FHL Tendinitis in Ballet Dancers

Lydia Yun, B.S.; Dara Taeb B.S.

INTRODUCTION
Ballet as an artistic endeavor is unique in that it requires great physical skill and puts great physical demand on the body. Research examining physical performance profiles compares dancers to the most elite athletes in competitive sports. The prevalence of injuries in dancers has been estimated between 40-80%, depending on the level of dance participation. A lifetime incidence of up to 90% has been shown in dancers. In a study which followed a classical ballet company, 95% of dancers employed for more than one season sought medical consultations at some time during the five year study period. Ballet dancers train to build strength, refine balance and increase flexibility based on fundamental principles like repetition and discipline. There is no question that ballet is a high demanding activity. Therefore, it is not surprising that most injuries sustained by the dancers were found to be overuse type injuries.

Ballet dancers require a certain type of physique such as exceptional joint mobility especially in the spine, hips and feet, if they are to avoid injury. Executing movements primarily in “turn out” and holding extreme unnatural postures require and induce a unique anatomical makeup, particularly in females who dance en pointe. While men have been more affected by traumatic injuries such as distortions, contusions and sprains; women are more prone to overuse injuries, especially about the foot and ankle regions. Up to 40% of dancer’s injuries were located in the lower extremity and due to overuse. Most of these injuries were soft tissue injuries involving ligaments and muscles about the ankle. High performance standards, rigorous training and unusual circumstances can make dancers prone to uncommon injuries. The most common of these is inflammation of several tendons about the ankle, most notably the flexor hallucis longus (FHL) tendon. Clinicians have come to learn that dancer’s tendinitis is almost always the FHL. The purpose of this paper is to conduct a qualitative systematic review of literature on a pathology very common and unique to dancers - flexor hallucis longus (FHL) tendinitis.

BALLET DANCER’S PREDISPOSITION TO FHL TENDINITIS
Why is FHL tendinitis more common to ballet dancers than other athletes? The frequency of FHL tendinitis could be due to the repetitive movements in often non-anatomical positions that create prolonged stress and very high loads of strain on muscles and ligaments. One of the activities that was found to contribute most to tendinitis because of its nature and repetition was relevé, going into the demi pointe position, then into en pointe. A ballet dancer must obtain at least ninety degrees of plantarflexion in the ankle joint, enough to extend the axis of the leg through the metatarsals to the floor, in order to achieve the relevé positions of the demi-pointe and en pointe. These extreme ranges of motion make them particularly vulnerable to injury. FHL tendinitis seemed to be an extremely common injury in semi-professional to professional classical ballet dancers across the studies that were reviewed or only seen in persons who participate in activities requiring frequent push-off maneuvers. These positions rely on the integrity of being able to flex the big toe at the 1st metatarsophalangeal joint (MPJ) and 1st interphalangeal joint (IPJ), both of which are executed by the FHL muscle. Excessive plantarflexion and dorsiflexion at the ankle are inherent to pointe work. As the FHL passes through a fibro-osseous tunnel from the posterior aspect of the talus to the level of the sustentaculum tali, it passes much like a rope through a pulley. In full plantarflexion (pointe), the tendon is compressed in its groove inside a fibrous sheath over the posterior talar tubercle. In dorsiflexion, the tendon is stretched between the posterior talar tubercle and sustentaculum tali. Constant repetition of these movements through plié, relevé and jumps in which the FHL serves as the...
accessory push-off muscle can cause inflammation. The FHL is the last tendon to come in with take-off and the first to take shock when the dancer lands; thus it is subject to a large eccentric load on landing. This source of compression can be irritating to the tendon itself, the soft tissue and the posterior capsule of the ankle. When strained the FHL begins to bind, rather than gliding smoothly as a pulley. This causes irritation and swelling, which in turn causes further binding, irritation, swelling, then thickening and fibrosis of the tendon sheaths and setting up a cycle.1,4,12,13,14 The contorted, non-anatomical maneuvers of modern dance and the rigidly defined positions and steps of ballet necessitate placement of the feet and ankles in positions that are extremes of the range of motion of the joints that require excessive demands of the body. This leads to inflammatory processes that are further aggravated by a strenuous rehearsal and performance schedule.15 Interestingly, ankle tendinitis occurs more often in the left foot than the right foot. This is because there are more choreographic turns to the right than the left, meaning the dancer must be en pointe on the left foot more often than the right.16 This supports that the act of relevé and plié is a primary aggravating factor for FHL tendinitis.

Incorrect ballet technique is the cause of a large number of clinical presentations among ballet dancers.5 Forced turnout frequently contributes to overuse injuries. Turnout is determined by the anatomy of the hip joint. When full turnout is not possible in the hip joint, compensatory turnout is required in the knee joint and/ or ankle joint, resulting in increased torsional forces on these joints and greater risk of injury.3,17 Clinicians found that dancers who encountered FHL tendinitis tended to pronate because of poor alignment and faulty technique.12 If the trunk musculature is not strong enough, nor the dancer’s balance sensitive enough to hold the dancer precisely over the pelvis, the ankle will rock excessively between inversion and eversion when the dancer is on demi-pointe. This causes fatigue in the medial and lateral ankle muscle groups. When turnout is forced from the floor upwards, it forces the tibia to externally rotate the knee. This leads to the resulting excessive pronation causing the plié to fall inside the foot, rather than over the 2nd ray, where the projected axis of the femur should be when the knee bends. It also leads to difficulty in re-supination of the foot to go en pointe. This can lead to over stress and injury to the FHL.3,14 Thus, it is not surprising that tendinitis seems to occur more often in relatively “tighter dancers”, such as those with stiff feet and incorrect pointe position.11,16

While the “stressor event” of repetitive plié and relevé were the most frequently cited causes of FHL tendinitis, other potential causes have been noted. More than one source has attributed poorly fitted ballerina shoes as a possible cause.4,16 The ballet shoe is of very old design and gives little support to the foot, placing additional strain on the FHL tendon. More directly, the pointe shoes and its ribbons impose compression and friction upon the tendon. The floors of many major stages are sloped. Uneven ground requires sudden adaptation of the foot during normal ambulation, and is nonetheless increased while dancing.

Other articles mention that exostosis of the dorsal surface of the talus is not an uncommon problem in dancers. Decreased bony protection in the planarflexed position (due to the wedge shape of the talar dome), combined with decreased ligamentous stability on top of chronic overuse of the same muscles will likely lead to tendinitis.7,16 Os trigonum syndrome, a diagnosis commonly cited together with FHL tendinitis, also may contribute to tendinitis. An os trigonum may impinge the FHL tendon, leading to posterior ankle pain.18

**TYPICAL MANIFESTATION OF FHL TENDINITIS**

Patients with FHL injury describe an insidious onset of pain in the tarsal tunnel along the posteromedial aspect of the ankle behind the medial malleolus or the medial aspect of the subtalar joint plantar to the sustenaculum tali.2,4,9,10,13,25 Because the tendon is under maximum stretch in the demi-plié position (in which the toe and ankle are dorsiflexed), pain is felt at the posterior ankle or under the hallux at the depth of the demi-plie or grand plié when jumping or rising to a demi-point or en pointe position.3,5,19 Pain or crepitus along the FHL can be reproduced when the foot is maximally pointed in extreme plantarflexion of the ankle, foot, MPJs and IPJs as well as when the patient flexes the hallux against resistance.3,11,12,14,19,20 Pain, tenderness and mild swelling can potentially be found overlying the entire length of the FHL tendon.5,13,14,20

During physical exam, one can compare the amount of passive extension of the 1st MPJ with the foot and ankle in neutral versus plantarflexed positions. An FHL injury will yield little to no extension in the neutral position but normal passive extension in planatarflexion.5,20 A case study on a ballerina with bilateral FHL tendinitis showed an initial normal FHL function with regards to ROM. A year later without treatment, examination found complete absence of active flexion of the IPJ of the left hallux and severe weakness of the IPJ in the hallux with the ankle in neutral position.20

**FURTHER MANIFESTATIONS**

Alongside the characteristics mentioned above, FHL tendinitis frequently presents with clicking or triggering during movement of the hallux. Dancers may
complain that the hallux may lock during demi-pointe work and are unable to release when going into plié. Alternatively, when the ankle is in full plantarflexion, the hallux may lock into plantarflexion causing difficulty with dorsiflexion. On occasion, nodules develop on the FHL tendon, preventing it from passing freely through its fibro-osseous tunnel, resulting in the trigger toe. In extreme cases, the tendon becomes stuck in the tunnel, causing the tendon tissue to tear, leading to the formation of scar tissue and adhesions. This further prevents the tendon from gliding smoothly through its tunnel. Ultimately, the hallux may become immobilized in the plantarflexed position, forcing the dancer to manually pull the toe back into its neutral position. Partial rupture of the FHL in classical ballet dancers was attributed to ruptures at the central fiber of the tendon.

The pain caused by FHL tendinitis tends to become chronic. Movement patterns performed repetitively which do not allow sufficient time for tissue repair result in cumulative microtrauma. Chronic tendinopathy of the FHL leads to chronic pain, early arthritis of the 1st MPJ and 1st IPJ and fibrosis with decreased range of motion. If chronic, one may find retinacular cysts on or within the tendon sheath. The tendon can become entrapped at several sites resulting in stenosing tenosynovitis and develop partial longitudinal tears.

Once an injury has occurred, especially if it is minor enough to allow the dancer to continue working, further injuries may follow. This is likely due to manifestations of the initial injury leading to alterations in accurate technique to avoid overstraining and achieve temporary relief. However, the altered technique has a high predisposition of further injury and complications. FHL tendinitis can become recurrent and disabling.

FHL tendinitis may cause secondary manifestations to occur in other areas of the foot. The dancer may tend to roll toward the lateral aspect of the foot to avoid extreme dorsiflexion of the hallux. An example, in one dancer, her second toe crossed over her hallux in non-weight bearing pointe position to compensate for a limitedly functional hallux.

Examination for FHL tendinitis should include radiographs of the ankle in the AP, mortise, and two lateral views, one in the normal weight-bearing position, and one in the pointe position. Recurrent or recalcitrant cases should consider a complete blood count, erythrocyte sedimentation rate, latex fixation, uric acid and chemical profile. Magnetic resonance imaging (MRI) can demonstrate tendon degeneration and fluid surrounding the tissue. Ultrasound examination can be helpful as well if any doubt of clinical diagnosis exists.

**MISDIAGNOSIS**

Posterior Ankle Impingement (PAI) Syndrome or talar compression syndrome is often mistaken for FHL tendinitis. Pain in a dancer with PAI Syndrome usually manifests posterolateral to the ankle where the posterior lip of the tibia closes against the superior border of the os calcis when the ankle is plantarflexed as demonstrated in tendu, frappe or relevé positions, or in taking off during a jump. Conversely, a dancer with FHL tendinitis would have pain or triggering at the ankle posteromedially with motion of the hallux. To differentiate between the two diagnoses, the physician can inject 0.85 mL of lidocaine into the soft tissues of the posterior ankle behind the peroneal tendons. If the pain is not relieved, PAI syndrome is likely.

Other common misdiagnoses include Achilles tendinitis and fibrous subtalar coalition. Achilles tendinitis usually presents with pain or discomfort either diffusely on the posterior aspect of the leg or localized to the ankle near where the tendon attaches to the calcaneus. Fibrous subtalar coalition should be suspected when there is limited range of motion at the subtalar joint. This can present with cramping or pain in the medial or posteromedial ankle, mimicking FHL tendinitis or tarsal tunnel syndrome.

**TREATMENT OF FHL TENDINITIS IN BALLET DANCERS**

In treating FHL tendinitis amongst ballet dancers, both conservative and surgical procedures are considered. In many cases, however, non-surgical approaches have been unsuccessful, and surgery was then considered. Although the majority of dance related overuse injuries require surgery, the number of successful recoveries made with conservative treatment is measurable and significant, and therefore must be considered as a first line of therapy before surgery. Non-steroidal Anti-inflammatory drugs (NSAIDs) were deemed useful in managing pain during conservative treatment. Physical therapy including home strengthening exercises and realignment work showed improvement before the patient returned to full activity and to specifically re-assume the en pointe position. Shoes with a firm sole and high arch were recommended to relieve stress on the FHL tendon both as a conservative measure and post-operatively. One study also showed that underwater ultra-sound therapy was occasionally successful.

Although conservative treatments produce a significant number of recoveries, surgical intervention has shown to be very effective with few complications. The goals of surgical procedures are to repair degenerative
The injury results from overuse of the musculoskeletal and musculotendinous structures of the lower extremity. The injury can lead to career ending complications, as the physical and mental burdens of professional ballet dancers are very comparable to professional athletes in other sports. Both conservative non-surgical and surgical treatments are used for the injury. Although effective, conservative treatment can be unsuccessful and surgical invasion is then deemed necessary. Surgical intervention has shown to be very effective with FHL tendinitis and little post-operative complications were shown to occur. As a future consideration, it has been shown that blood supply to both areas affected by FHL tendinitis show measurably less vascularity compared to the rest of the foot, and it would be interesting to see further studies concerning this finding.\textsuperscript{25,27}

CONCLUSION

FHL tendinitis is a common and unique injury found almost exclusively amongst classical ballet dancers.

REFERENCES


Distraction Osteogenesis as a Treatment for Brachymetatarsia

David H. Tien, M.S.; Anna K. Tien, B.S.

Distraction osteogenesis was developed in 1951, using a circular external fixation system that utilized transfixation wires. In 1956, while performing an open osteotomy of the knee, distraction with external fixation and bone grafting, Ilizarov noted new bone formation within the distraction space. This observation led to the discovery of the Tension-Stress Principle, which explained the response of the tissue to elongation. The Tension-Stress Principle states that “living tissue, when subjected to a slow steady traction, becomes metabolically active in both biosynthetic and proliferative pathways”, a phenomenon dependent on vascularity and functional use.

In 1956, while performing an open osteotomy of the knee, distraction with external fixation and bone grafting, Ilizarov noted new bone formation within the distraction space. This observation led to the discovery of the Tension-Stress Principle, which explained the response of the tissue to elongation. The Tension-Stress Principle states that “living tissue, when subjected to a slow steady traction, becomes metabolically active in both biosynthetic and proliferative pathways”, a phenomenon dependent on vascularity and functional use.

In 1987, De Bastiani et al. used the tension-stress principle to create callus distraction. Callus distraction is a technique that involves slow distraction of the callus that formed at the distraction site as the bone heals. This technique utilizes a dynamic axial fixation device (Figure 1) that allows for gradual telescopic movement, allowing dynamic distraction without removing the device. The key difference between De Bastiani and Ilizarov technique is that De Bastiani allowed significant bone callus to develop before the gradual distraction period is started. However, the two terms are used interchangeably today.

Following the tension-stress principles, an external fixator should achieve: (1) percutaneous treatment of all closed metaphyseal and diaphyseal fractures, and many epiphyseal fractures; (2) repair of extensive defects of bone, nerve, vessel, and soft tissues without the need for grafting; (3) bone thickening; (4) percutaneous, one-stage, treatment of congenital or traumatic pseudoarthroses; (5) bone lengthening (Figure 2, 3); (6) correction of long-bone and joint deformities; (7) treatment of various arthroses by osteotomy and repositioning of articular surfaces; (8) percutaneous joint arthrodesis; (9) lengthening of amputation stump; and (10) correction of achondroplastic and other forms of dwarfism.

Figure 1: A unidirectional, single-rail dynamic axial fixators [Photo courtesy of Lippincott Williams & Wilkins Publisher].

LOCATION OF DISTRACTION

Callus distraction can occur at the growth plate, in epiphyseal bone, in metaphyseal bone, or in diaphyseal bone. The epiphysis should be only used when the growth plate is still open. However, the integrity of the physis may be compromised because if distraction rate is too fast, it can lead to early closure of the growth plate. When distraction occurs too fast, the gap can be filled with hematoma that will lead to trabecular bone formation and early growth plate closure.
Proximal metaphyseal bone has a larger diameter compared to diaphyseal bone, which yields a greater surface area for regeneration.\textsuperscript{4,6,8} Stability is also enhanced in metaphyseal bone due to abundant soft tissue in the area, offering stability via muscular and ligamentous attachments. There is increased vascularity with increased soft tissues, promoting better healing.\textsuperscript{4,6,8,9} Thus, it is the preferred location for osteotomy. Diaphyseal bone presents as an easier site for fixation due to its longer length.\textsuperscript{5,7,8}

**INDICATIONS/CONTRAINDICATIONS**

Callus distraction is often used in conjunction with tibial osteotomies, medial column osteotomies, Evans calcaneal osteotomies, brachymetatarsia repair, iatrogenically shortening metatarsals, congenital or traumatic shortened limbs, and more.\textsuperscript{4,8} The usage of callus distraction is contraindicated in noncompliant patients because of the rigorous course of the postoperative management.\textsuperscript{4,8}

**ROLE OF PERIOSTEUM**

Periosteum and endosteum play an important role in bone healing because the osteoprogenitor cells in the periosteum and endosteum lay down spongy bone to replace temporary callus during the process of bone healing.\textsuperscript{7,8} In 1988, Kojimoto et al. performed distraction osteogenesis on three cohorts of rabbits to determine the role of periosteum in bone healing.\textsuperscript{9} One cohort had their periosteum opened and reapposed afterward. In the second cohort, a segment of the periosteum surrounding the osteotomy was removed. In the third cohort, the endosteum was scraped out after the osteotomy, and the periosteum was put back together afterward.\textsuperscript{9}

Out of all the cohorts, only the second cohort with the periosteum removed showed a significant impairment in bone healing, while the other two groups were basically identical. This suggests that preservation of periosteum is essential in bone healing and callus distraction.\textsuperscript{7,9} Thus, the periosteum should be left intact and the surgeon should perform the osteotomy through it, creating less trauma to the periosteum compared to it being cut.\textsuperscript{4}

**CORTICOTOMY VERSUS OSTEOTOMY**

The procedure is performed while the patient is in a supine position.\textsuperscript{4,7,8} Fluoroscopy is utilized to ensure accurate placement of the pins.\textsuperscript{4,7,8} Typically, the patient can tolerate the procedure under Monitor Anesthesia Care (MAC) and local blocks of the foot.\textsuperscript{4,8} Ankle tourniquet is preferred and typically can be set at 250 mmHg.\textsuperscript{4,8}

---

*Figure 2: Clinical presentation of brachymetatarsia of the fourth metatarsal on right foot [Photo courtesy of Dr. Bradley M. Lamm].*

*Figure 3: Radiographic presentation of brachymetatarsia on fourth metatarsal from same patient as figure 2 [Radiograph courtesy of Dr. Bradley M. Lamm].*
This is a one-incision approach method. One dorsal linear incision is made over the distal aspect of the cuboid or respective cuneiform that is associated with the metatarsal of interest. The incision is continued distally in the affected metatarsal. This approach offers superior visualization and if the corresponding digit needs surgical correction or treatment, then the incision can be extended distally.

The incision should be placed centrally on the metatarsal and usually extends distally past the midshaft of the metatarsal. Careful dissection should be made down to the deep fascia layer while maintaining hemostasis. Then an incision is made through the fascia and stopped either laterally or medially to the extensor tendon, which will be retracted either be retracted medially or laterally to the pins (Figure 4). Tendon lengthening is not necessary as the tendons will lengthen with the gradual distraction of the bone.

The location of the osteotomy should be identified and marked with a skin marker prior performing the osteotomy because visualization of the proximal metaphysis can be challenging due to the adjacent bones. After the osteotomy site is marked, pins should be placed. This will maintain the stability of the metatarsal because if the osteotomy where to be performed first, the metatarsal stability will be compromised and it will be difficult to insert the pins. A total of four pins will be inserted: two pins as close as possible to the osteotomy and two pins as far away – as allowed by the fixation device – as possible from the osteotomy (Figure 5).

The most proximal of the distal pins is placed first to ensure that it is not too close to the planned osteotomy. Once the first pin is in, the external fixator can be used as a guide for the other pins placement.

The pins must purchase both the dorsal and plantar cortices. The second pin is placed most distally from the osteotomy. The third pin is the proximal pin closest to the osteotomy. The fourth pin is the most proximal pin that is placed in either the base of the affected metatarsal, cuboid, or the respective cuneiform.

After the pins are inserted, a through-and-through osteotomy can be made at the proposed site. After the osteotomy, a distraction of the osteotomy can be done to help visualize the gap (Figure 6). After visualization of the gap, the osteotomy is compressed, and the external fixator is removed. Layered closure of the deep fascia and subcutaneous tissue is performed with absorbable suture, while the skin edges are realigned with nonabsorbable suture (Figure 7). One must take careful measure to avoid tangling sutures around the pins.

After wound closure is performed, the external fixator is placed back on, and the osteotomy is compressed for approximately seven days. There should be about one finger width (approximately 1.50 cm) space between the plantar surface of the external fixator and the dorsal surface of the skin to allow room for wound care, dressing, and post-operative edema. Topical antibiotics (such as xeroform impregnated with bismuth tribromophenate; adaptec soaked in betadine; silver products; bacitracin; triple antibiotic ointment or cream; or any other antibiotic product) are applied around the pin sites, then dry sterile dressing are applied. A soft compression dressing can be applied and placed over the frame and pins. The tourniquet is deflated, and a posterior splint is applied. Patient
will be non-weight-bearing until the fixation device is removed, and must return to clinic weekly for inspection of the pin site for infection, and follow-up of the distraction process.

Figure 6: Distraction of the osteotomy site to visualize a complete through-and-through osteotomy [Photo courtesy of Lippincott Williams & Wilkins Publisher].

Figure 7: Skin closure with nonabsorbable suture [Photo courtesy of Lippincott Williams & Wilkins Publisher].

POSTOPERATIVE MANAGEMENT OF DISTRACTION OSTEOGENESIS

Callus distraction postoperative management plays a vital role in the outcome of the procedure. The success of the procedure is dependent upon patient compliance because the final correctional result is not obtained until the external fixator is removed. Changing of the dressings to prevent infection and for monitoring of the external fixator should be done 3 to 4 days postoperatively. During each visit, the pin sites are cleansed with peroxide and antibiotic ointment is applied.

Distraction is performed at postoperative day 7, but may be delayed for as long as 3 weeks. Immediate distraction at the time of the osteotomy can facilitate fibrin deposition and decrease bone formation. Latency period, the time between surgery and the beginning of the distraction, plays an important role in aiding the increase in vascularity and potential for bone formation.

Mini external fixators allow 1 mm of length per full revolution of turning. The best rate of distraction for brachymetatarsia repair is 5/8 mm (0.625 mm) a day, which equate to 1/8 turn five times per day. The recommended distraction rate is 0.25 mm every 12 hours, which is 1/4 turn twice a day. Best results are obtained by smaller and more frequent turning intervals; however, for patient compliance, one-quarter turns are more common.

Gradual lengthening is an essential part in this procedure because not only does it dictate the process of the bone healing, but it also help minimized the risk of neurovascular compromise when compared to acute lengthening. Excessive lengthening can cause soft tissue tension, which can damage the neurovascular supply. Acute lengthening cannot go beyond 10 mm of distraction in order to protect neurovascular structures.

Patients are evaluated weekly; when the optimal length is obtained, the distraction site is allowed to completely consolidate and the patient is seen every 2 weeks (Figure 8). The pins and frame are left in place at this time, and this period is known as the ossification period. The newly obtained length should not exceed 40% of the original length of the metatarsal, and the callus distraction process takes about 3 to 4 weeks.

Skin sutures are removed at 3 weeks. Once the sutures are removed, patients can perform proper pins care daily, keeping the pin sites dry. Patients remain in non-weight bearing posterior splints during ossification period. Once bony consolidation is observed on x-ray, the patient may weight-bear with the external fixator in place. The most distal and proximal pins can be removed after 2 weeks of weight-bearing, and the remaining pins and external fixator frame can be removed 2 weeks following that. Patient may resume full weight-bearing in a surgical shoe and gradually progress to normal shoe gear once all the pins are removed.
PROCEDURE: PERCUTANEOUS DISTRACTION OSTEOGENESIS

Percutaneous osteotomy is advantageous over the one-incision approach distraction osteotomy for many reasons: (1) limited devascularization of surrounding tissues, (2) preservation of endosteum and periosteum, (3) improve bone formation regeneration, and (4) reduce scar formation.\(^7\)

Overall the technique is very similar to the one-incision approach with some slight differences; this is a multiple incisional approach.\(^7,8\) The first incision is over the proximal metaphysis of the affected metatarsal. This is where you will perform the osteotomy. Then several small stab incisions are made over the distal and proximal pin sites.\(^8\)

Four half-pins are inserted percutaneously under fluoroscopic guidance. Half-pins will be inserted bicortically and perpendicular to the shaft of the metatarsal. Prior all insertion of half-pins, a 1.8mm wire will be used to predrill the hole concentrically under fluoroscopic guidance.\(^7\) It is important that the wire is perpendicular to the metatarsal on lateral view. Then a small stab incision is made with a #64 scalp blade.\(^7\) The wire is then removed, and a 2.5mm half-pin can be inserted. Typical half-pin used in this procedure would be 80mm in length with 15mm of tread length.\(^7\)

The first half-pin will be inserted at the distal most aspect of the metaphyseal-diaphyseal junction. The first pin is important in determining the plane of lengthening because the external fixator will be mounted perpendicular to it.\(^7\)

The second half-pin is the most proximal of the four half-pins, and it is inserted in the proximal base of the metatarsal. The second pin is important in establishing the direction of the metatarsal lengthening since two point creates a line.\(^7\) Furthermore, the location of this pin is essential in preventing the metatarsal from lengthening into an adjacent metatarsal.

The third half-pin will be inserted just distal to the second half-pin at the base of the metatarsal. Finally, the fourth pin is inserted just proximal to the first half-pin (Figure 9).

If the metatarsal is really short, then the most proximal half-pin (the second half-pin) may be placed in the tarsal bone instead, but generally, all four half-pins can be placed in the metatarsal.\(^7\) After the placement of the all the half-pins, MTPJ stabilization technique of your choice can be performed.

The osteotomy of the metatarsal will be made percutaneous, and a 5mm percutaneous incision will be made lateral to the short metatarsal at the proximal metaphyseal-diaphyseal junction and between the two metatarsal half-pin clusters (Figure 9).\(^7\) A small Hoke osteotome will be used to complete the osteotomy under fluoroscopy guidance. Be careful not to make an osteotomy in the adjacent metatarsals. After a through-and-through osteotomy is made, the osteotomy site is then reduced by using the external fixator. Percutaneous osteotomy incision is closed, and compressive dressing is applied around all six pins and the foot.
Figure 9: Intraoperative photograph showing the percutaneous metatarsal osteotomy technique. Note the placement of the half-pins and how the assistant is applying counter pressure on the medial aspect of the foot. The osteotome is held against the foot to avoid bulging with the osteotome [Photo courtesy of Dr. Bradley M. Lamm].

POSTOPERATIVE MANAGEMENT OF PERCUTANEOUS DISTRACTION OSTEOMERATION

Postoperative management is the same as one-incision approach, except a slight change in the rate of distraction method. The rate of distraction is the same as the one-incision approach distraction osteogenesis, which is 0.5mm/day. However, for percutaneous distraction, it is recommended that the patient turns the bolt three times per day as oppose to two times per day; and each of those turns is 1/6 of a circle, resulting in 0.5mm/day.7

MTPJ STABILIZATION

Stabilization of the MTPJ during the lengthening procedure will help prevent subluxation of the joint. MTPJ stabilization is commonly done after all the pins have been inserted into the metatarsal.4,7,8

The most common and easiest way for stabilization is Kirschner-wire (K-wire) pinning (Figure 10); however, this will cause mild to severe joint stiffness postoperatively regardless of the duration the pin is being placed in there.7,8

A newer technique to preventing subluxation of the joint without the postoperative joint stiffness and chondrolysis of the MTPJ is by using a second external fixation. This external fixator pin will be clamp to the rail to distract the MTPJ concurrently with the distal segment of the metatarsals.7

Two small percutaneous dorsal stab incisions will be made with a #64 scalpel blade at the base of the proximal phalanx of the corresponding short metatarsal. Two treaded 16mm pins will be placed through the two incisions.7 The pins then will be an attached to a third external fixation pin clamp, which is mounted distally on the distraction bar, or rail. It is mounted in approximately 15 degree of flexion relative to the metatarsal declination angle (Figure 11).7

Once the osteotomy in the metatarsal has been made, the two treaded pins will be connected to the external fixator block (pin clamp); thus, creating a "second fixator". The corresponding toe will be reduced into rectus position, and the pin block will be attached to the distraction bar. This third pin clamp functions to maintain the toe in rectus position and to protect the MTPJ from subluxation and compression, which leads to limited range of motion or stiffness (Figure 12). Reduction of the toe to the rectus position includes acute distraction of the MTPJ by approximately 3mm, while manually loading the forefoot.7

Figure 10: A K-wire is inserted though the 4th MTPJ to prevent subluxation of the joint during the lengthening process [Radiograph courtesy of Lippincott Williams & Wilkins Publisher].
Figure 11: The intraoperative fluoroscopy shows the two threaded pins that are inserted in the proximal phalanx of the short metatarsal at a 15 degree flexion angle relative to the metatarsal declination angle [Radiograph courtesy of Dr. Bradley M. Lamm].

Figure 12: A and B represent the 1st fixator that is use for distracting the metatarsal and is composed of the 1st and 2nd pin clamps. C represents the second fixator that is use to prevent subluxation of the MTPJ, and it is also the 3rd pin clamp. The pin clamp is the blue block that attaches the pins to the rail [Photo courtesy of Dr. Bradley M. Lamm].

COMPLICATIONS
Over-lengthening of the bone may cause subluxation of the metatarsal phalangeal joints (Figure 13) and deviation of the digit due to the failure of the tendons to adapt to the changes of the bone.2-4,8,14 Arthritic changes and/or decreased range of motion may be observed secondary to the subluxing of the joints.2-4,8,11-13

Hypertrophic scarring (figure 14), is an additional complication that may occur. This is caused by the lengthening of the skin and surrounding soft tissues. If patient’s distraction rate is too slow, there may be a lack of trabecular bone formation, known as chondrodiatasis. When the distraction occurs too rapidly, nonunion, hematoma, and formation of trabecular bone may arise, and this is known as distraction epiphysiolysis.4,8

Other complications include but not limited to pin loosening and pin tract infection. Pin loosening may be caused by noncompliance or trauma postoperatively, and can be corrected by tightening of the device. Close monitoring is needed to prevent pin tract infection. If an infection is observed, local pin and wound care and oral antibiotics should be initiated immediately. Nonunion is rarely reported.3,8,11

Figure 13: Image A, the patient has overturned the device and overlengthening of the metatarsal was the result. Image B, 8 months status post shows the subluxation of the 4th MTPJ joint as a result of the overlengthening [Radiograph courtesy of Lippincott Williams & Wilkins Publisher].
CONCLUSION
Distraction osteogenesis has proven to be a reliable and effective technique in bone lengthening regarding bone salvage and reconstructive surgery. This procedure allows for early post-operative weight-bearing and minimal scarring if the percutaneous osteogenesis distraction is performed. Major complications of distraction osteogenesis include stiffness, subluxation of MTPJ, non-union, delayed union, and angulation. However, the complications risk can be reduced by maintaining the periosteum, gradual distraction rate, and avoiding excessive bone-lengthening. The key success to the outcome of this procedure is patient education. Patient compliance has a significant effect on the final outcome of the procedure because the patient is the one distracting the device daily.

ACKNOWLEDGMENTS
We would like to thank Dr. Bradley M. Lamm and Lippincott Williams & Wilkins Publisher for allowing us to use their radiographs and photographs in this review article.

REFERENCES
1. Ilizarov G. A method of uniting bones in fractures and an apparatus to implement this method, USSR Authorship Certificate 98471, filed 1952.
The Efficacy of Alpha-Lipoic Acid in the Symptom Relief of Diabetic Peripheral Neuropathy

Michelle Vi Nguyen, B.S; Francisco Mendivil-Moreno, B.S., M.P.H; Binh Ta, B.S.

INTRODUCTION
Diabetic peripheral neuropathy (DPN) is a condition in which patients with diabetes mellitus experience uncomfortable or painful sensations as a result of compromised nerve and microvascular integrity. These symptoms can manifest as motor, sensory, and/or autonomic abnormalities. The presentation of symptoms is most often localized as a moccasin/stocking distribution in the lower extremities. Up to 50% of patients with diabetes experience symptoms of peripheral neuropathy and approximately 30% of diabetic patients will experience distal sensory peripheral neuropathy.1,2

Diabetic peripheral neuropathy commonly presents as sensory neuropathy. Patients often complain of bilateral burning, tingling, numbness, paresthesia, and shooting pain. Symptoms are classically exacerbated at night. Symptoms may present as chronic, intermittent pain not associated with ambulation or activity, however, they may be worsened with activity. As podiatric physicians, the most concerning and pertinent symptom to be aware of is the loss of protective sensation.1 Insensitivity to pain increases the risk of ulcerations of the foot which often remain undetected by the patient for a long period of time. This can lead to severe repercussions such as infection, amputations, and/or limb loss.3

Motor deficits are not uncommon in DPN. The anterior muscle compartment of the leg is more commonly affected than the posterior group. Symptoms may manifest as muscle weakness and can result in altered plantar pressure or decreased dorsiflexion of the ankle4. This can lead to abnormal balance, digital contractures, increased metatarsal head prominence, and equinus.5 These musculoskeletal problems may lead to issues for diabetics and may exacerbate the risk of diabetic foot infections.4

Lastly, DPN can manifest as autonomic/sympathetic symptoms which affect the temperature and amount of hidrosis of the lower extremities. Sympathetic neuropathy may present as hot or cold. Symptoms patients describe as “hot” may include increased perspiration, warmth in the lower limb, erythema, and may create an environment for bacterial and fungal growth. Symptoms that are described as “cold” are characterized by decreased sweating, clammy feet, and can cause dry, cracked plantar skin.3 Excessive dryness from hypohidrosis can lead to callus formation which is a predictive factor for the development of ulcers.4

Research suggests that the pathogenesis of DPN is due to oxidative stress.5 Chronic elevated blood glucose compromises the microvasculature to the lower extremities and impairs the endoneurial vessels. The basement membrane of vessels thicken, endothelial cell proliferation occurs, and oxygen tension is reduced.6 Nerve fiber dysfunction begins and may result in sensory symptoms of burning, numbness, tingling, and pain, in addition to the presence of motor and autonomic abnormalities.1

The treatment for symptoms of DPN is innumerable. There are well established treatment regimens that are centered on medications for symptom relief. Current pharmacological treatments for painful DPN include tricyclic antidepressants (TCAs), serotonin-norepinephrine reuptake inhibitors (SNRIs), and alpha-2 agonists. Neuropathic symptoms are most commonly managed by GABA analogs such as gabapentin and pregabalin1. More potent opioid combinations such as tramadol and oxycodone have been tried for uncontrolled, severe neuropathic pain and have confirmed efficacy in symptomatic relief of diabetic neuropathy pain for short term use.1,6 Another approach to alleviating diabetic neuropathic pain is to halt or slow the pathogenesis by utilizing vitamins and antioxidants. Vitamin B12 has been shown to improve neuropathic symptoms especially in patients with decreased B12 absorption due to daily Metformin ingestion.7 The only antioxidant currently supported by clinical trials is alpha-lipoic acid (ALA)8.
This antioxidant has been shown to improve endothelial function by increasing nitric oxide mediated endothelium dependent vasodilation. By impeding oxidative stress, neurological function to the lower extremities is expected to improve thus reducing symptoms of DPN.\textsuperscript{5} Studies show that ALA is efficacious in improving antioxidant defense and decreasing the oxidative stress in patients with and without poor glycemic control. In addition to treating DPN, ALA may help with diabetes control by increasing glucose uptake into cells. In cultured fat and muscle cells, ALA has been discovered to activate the insulin signaling pathway to increase translocation of GLUT4 channels to the surface of the cell membrane. This increases glucose uptake into cells and decreases blood glucose level.\textsuperscript{8,9,10} This demonstrates that ALA administration is a possible new non-invasive method of decreasing oxidative which may also aid in better glycemic control with no reported adverse effects.\textsuperscript{11} However, other studies have indicated that oral administration of ALA have caused adverse drug reactions including allergic skin reactions, hives, itching, abdominal discomfort, nausea, vomiting, diarrhea, vertigo, and malodorous urine.\textsuperscript{13,14} One study has even indicated an occurrence of anaphylactic reaction and laryngospasm with intravenous administration of ALA.\textsuperscript{15}

Alpha-lipoic acid efficacy is assessed by several methods. The Total Symptom Score (TSS) is a questionnaire that patients fill out to help qualify their symptoms.\textsuperscript{12} Neuropathic symptoms are scored by the physician regarding intensity as described by the patient. A score of 0 indicates no symptoms and a maximum of 14.64 points indicates all symptoms were severe and continuously present.\textsuperscript{15} The Hamburg Pain Adjective List (HPAL) is a scoring questionnaire filled out by the patient to qualify changes in pain severity and response to treatment.\textsuperscript{14} The Neuropathy Impairment score (NIS) is an objective composite scoring method to assess DPN symptoms. The parameters of the NIS include vibration detection threshold, peroneal motor nerve conduction velocity, peroneal motor nerve distal latency, peroneal compound muscle action potential, tibial motor nerve distal latency, sural sensory nerve action potential amplitude, and change in heart rate during deep breathing. Another objective method of measuring improvements in symptoms is nerve conduction tests. Electroneurography is utilized to quantify the signal conduction of axonal transmission for motor and sensory nerve conduction by the peroneal or tibial nerve, and sural nerve respectively. Platelet reactivity may be measured to gauge improvements of vascular integrity and symptom relief. High platelet reactivity is associated with increased blood clotting and viscosity which may lead to ischemia.\textsuperscript{15} Lastly, laser doppler is a non-invasive method of assessing blood flow when investigating DPN symptom alleviation.

**ORAL ADMINISTRATION**

In 2006, Ziegler, et al. demonstrated the efficacy of ALA in treating DPN with a once-daily oral dose of ALA for five consecutive weeks.\textsuperscript{16} This was a multicenter, randomized, double-blind, placebo-controlled study of 181 diabetic patients. Patients started a once-daily placebo dose for a one week single-blind, run-in phase, and then were randomly assigned to either continue the placebo or to switch to one of three different doses of ALA for five weeks. Forty-five patients received 600 mg of ALA (ALA600), 47 received 1,200 mg (ALA1200), 46 received 1800mg (ALA1800) and 43 continued to take the placebo. The primary outcome of the study was based on the change in Total Symptom Score (TSS) measured at the beginning and the end of the study. In addition, the Neuropathy Impairment Score (NIS) and the Patient’s Global Assessment were considered as secondary outcomes. Results revealed improvement of symptoms with significant decrease in TSS starting in the 2\textsuperscript{nd} week of treatment for all treatment groups except the placebo group ($p<0.05$). ALA1800 group showed earliest significant improvement starting in the 1\textsuperscript{st} week. Significant improvement in NIS was evident for ALA1200 group ($p<0.05$) while ALA1800 group only had borderline improvement ($p=0.055$). Global assessment results of “very good/good” in response to symptom improvements were 62%, 56%, 71%, and 29% for groups ALA600, ALA1200, ALA1800, and placebo respectively ($p<0.05$). All ALA groups showed significant improvement in DPN symptoms compared to placebo, however, the difference in mean TSS among the ALA groups was not significant. This indicates that the overall results were not dose dependent. Additionally, an increase in dose of ALA correlated with an increased occurrence of gastrointestinal side effects, making 600 mg of ALA a more favorable oral dose. With these findings, Ziegler et al. further explored the efficacy of the 600 mg ALA oral dose in subsequent studies.

In 2011, Ziegler et al.\textsuperscript{2} published results from their multicenter, randomized, double-blind parallel group trial using oral treatment of 600 mg of ALA. They specifically investigated the efficacy and safety of the oral administration of ALA in mild-to-moderate diabetic distal sensory polyneuropathy (DSPN). Subjects were included if they were type 1 or 2 diabetic for at least one year and had DSPN. 231 patients received 600 mg of ALA for 4 years. Two hundred and twenty-five patients received the placebo. The trial was conducted as a 4 year double blind phase and a 4 week washout phase. The efficacy of ALA was measured as change in NIS score. The results indicated that the change from
baseline NIS was significantly better in the ALA group compared to the placebo after 4 years. Patients showed improvement in symptom relief or slower progression in worsening symptoms with 600 mg oral administration of ALA. Nerve conduction and heart rate, however, did not significantly improve with the placebo.

Ruhnaut et al.\textsuperscript{16} led a monocenter, randomized, double blind, and placebo controlled trial. The patients enrolled in the study had type 2 diabetes and experienced neuropathic symptoms such as pain, burning, paraesthesia, and numbness. The treatment regimen consisted of one 600 mg ALA oral tablet three times a day (total of 1800 mg daily) for 3 weeks. Twelve patients were assigned to the treatment group and 12 patients were assigned to the placebo group. Efficacy was measured by TSS and the Hamburg Pain Adjective list (HPAL). The results showed a decrease of 47\% in TSS after 19 treatments over 3 weeks in the ALA group compared to placebo which had a decrease of only 24\% (\( p = 0.021 \)). The only significant decrease in TSS regarding individual symptoms with ALA was burning (\( p = 0.012 \)). Reduction of pain as indicated by the HPAL measurement was 60\% in the ALA group compared to 29\% in the placebo group but this was not statistically significant (\( p = 0.072 \)).

Bertolotto, and Massone investigated the efficacy of ALA in conjunction with another potent antioxidant, superoxide dismutase (SOD).\textsuperscript{17} The study was conducted as a prospective, non-randomized, open label study in which 50 patients with type 2 diabetes were instructed to take a tablet of 600 mg ALA + 104 IU SOD daily for 4 months. All subjects had diabetic sensomotor polyneuropathy. Symptom relief and treatment efficacy was measured by peroneal motor nerve conduction and sural nerve sensory conduction tests. The results indicated that symptoms significantly improved in the nerve conduction tests (\( p<0.001 \)) with ALA +SOD treatment. Patients also reported improvement in their pain.

INTRANEOUS ADMINISTRATION

Ametov et al.\textsuperscript{18} investigated the efficacy of intravenous ALA for type 2 diabetic patients with sensomotor polyneuropathy. This was a randomized, double blind, placebo controlled parallel study. The treatment group consisting of 60 patients received 600 mg of ALA intravenously for 5 days per week up to a total of 14 treatments. The placebo group consisted of 60 patients. The parameter measured was TSS to assess efficacy. The results showed that with 14 treatments of 600 mg IV ALA daily, the TSS of the treatment group decreased an average of 5.7 points while the placebo group decreased by an average of 1.8 (\( p < 0.001 \)). Statistically significant improvements were present for all items of the TSS in the ALA group compared to placebo. This includes but is not limited to: stabbing, burning, numbness, and prickling pain.

Jin et al.\textsuperscript{19} led a study that investigated the efficacy of ALA on symptoms of peripheral neuropathy and changes in skin blood flow. All patients enrolled in the study had type 2 diabetes and experienced neuropathic sensory symptoms which included pain, paraesthesia, and numbness. The study included 13 control subjects and 19 treatment subjects. The treatment group was given 600 mg/day of ALA intravenously for 30 minutes. Treatment lasted for 14 days. The parameters used to measure efficacy of ALA were TSS and skin blood flow set in arbitrary units. Blood flow was measured via a Laser Doppler Blood Perfusion Monitor at the dorsal aspect of both hands and plantar surface of both feet. The results showed no significant change in skin blood flow with intravenous ALA treatment after 14 days. TSS decreased significantly from 7.1 ± 1.59 to 1.9 ± 1.67 with ALA (\( p < 0.05 \)).

UNSPECIFIED ROUTE

There was one study that did not indicate the specific route of administration. Mollo et al. investigated the effects of ALA on platelet reactivity\textsuperscript{20} 51 type-1 diabetic patients without cardiovascular complications were enrolled in the study. Patients taking anti-platelet medications were excluded. Study participants were then randomly assigned to either the treatment group or the placebo. 26 patients were enrolled in the treatment group and received 600 mg of ALA daily for 5 weeks. 25 patients were placed in the placebo group. Blood samples were collected at the start and end of the study as well as after treatment, before insulin administration, and in a fasting state. Platelet reactivity was tested by the PFA-100 method to see amount of aggregation from platelet reactivity to collagen/ADP. The results showed that platelet reactivity had decreased with 5 weeks of ALA treatment for type 1 diabetics. When given 600 mg/daily of ALA, platelet aggregation had significantly decreased (\( p = 0.006 \)).

DISCUSSION

Diabetic peripheral neuropathy accounts for considerable morbidity, mortality and reduced quality of life and therefore must be managed by both patients and physicians in order to control blood glucose, cardiovascular status, and nutrition. Without these factors under control, symptoms of DPN such as burning, stinging, and numbness will manifest and/or worsen.

ALA may prove to be a promising treatment for DPN. Intravenous administration was able to produce results with statistically significant findings in both studies discussed. However, in the home setting, daily
intravenous administration of ALA may not be feasible for patients. A more practical route of administration of ALA may be subcutaneous injection as this method can be performed by the patient outside of the hospital setting, however, determination of the efficacy of ALA subcutaneous ALA administration requires future studies.

Overall the data has shown with and without statistical significance that ALA can improve patients’ neuropathic symptoms, even if the effects are mild at best. Further clinical trials need to be performed with more analogous treatment regimens and similar parameters measured to produce more justifiable instruction for ALA in treatment of DPN. ALA is a unique treatment option as it may ameliorate the cause of DPN rather than treating pain associated with ALA. Clinical trials of ALA exhibit neuropathic pain relief in conjunction with improved microvascularity, which makes this antioxidant a promising potential candidate in the DPN treatment regimen.

REFERENCES

Ledderhose Syndrome and its Relationship to Dupuytren’s Disease: Leading to Additional Treatments Options
Tara L Harrington MBA, MHA, Shanique Bingham

INTRODUCTION
Ledderhose Syndrome (Plantar Fibromatosis) is a benign and typically locally aggressive tumor consisting of fibrous tissue. It may be either superficial or deep, depending on the involvement of adjacent tissues. Dupuytren’s disease (Dupuytren’s contracture) is a fibro-proliferative disorder of the hand. Dupuytren’s causes thickening and contracture of the palmar fascia (palmar aponeurosis) which causes the fingers to flex and curl, differing from Ledderhose syndrome which leads to thickening of the plantar fascia and development of a fibrous nodule. Ledderhose syndrome does not typically lead to contractures of the phalanges. The etiology of Ledderhose Syndrome is unknown; genetics and repeated trauma to the plantar fascia are possible culprits.

Current conservative treatments of Ledderhose include off-weighting the area, stretching, footwear modifications, anti-inflammatory medications, steroid injections, and prefabricated or custom orthotics. Surgery is often ineffective. Recurrence rates are very high, with studies showing recurrence in up to 100% of the cases. Of all surgical options, removing the entire plantar fascia has been shown to be the most successful surgical treatment.

Conservative treatments for Dupuytren’s include physical therapy, needleing and enzyme injections. Physical therapy modalities include: heat, stretching, and ultrasonic waves. In a needleling procedure, a needle is used to puncture the skin and is placed into the contracted cord attempting to break it and relieve the contraction. Collagenase, an enzyme injection, has also been used. This treatment is usually followed by manipulation of the hand to stretch the thickened cord.

People who have a plantar fibromatosis have a higher incidence of Dupuytren’s contracture as well as other soft tissue abnormalities including knuckle pads, keloids, and subcutaneous/submucosal nodules that can be localized anywhere in the body. The extent of the relationship among all of these soft tissue abnormalities is unknown, because the cause is unknown, and the treatments vary in method and in success rates. Typically both Ledderhose and Dupuytren’s progress over several years, although there are cases of rapid progression. Both diseases seem to affect those of northern European descent and have an increased risk of occurrence associated with tobacco, alcohol, and diabetes.

The fibromatotic process of Ledderhose syndrome grows slowly and invades the skin and deeper structures. The similarities of this condition to those observed in Dupuytren’s disease seem to support the theory that the two diseases are expressions of the same disorder. A report in 2000 indicated the major cell responsible for plantar fibromatosis is the myofibroblast. This is similar to what is found in Dupuytren’s contracture. In many cases, a proportion of those with Ledderhose also have been found to have Dupuytren’s. In their study of 18 patients (23 feet) with Ledderhose, Sammarco and Mangone found that 28% also had Dupuytren’s.

DIAGNOSIS
Fibromatoses are a group of benign fibroblastic proliferations that vary from benign to intermediate in behavior. The imaging appearance of these lesions can be distinctive. Diagnosis of Ledderhose syndrome is most often through clinical appearance and location; pathological and histological findings mimic those of Dupuytren’s. Pathologically, lesions appear grayish
along with either a white or yellow tinge, depending on their collagen content, and histologically there is typically a homogeneous fibroblastic-myofibroblastic abundance of spindle-shaped cells.

Palmar fibromatosis presents with multiple nodular or band-like soft tissue masses arising from the proximal palmar aponeurosis and extending along the subcutaneous tissues of the finger, parallel to the flexor tendons. Plantar fibromatosis presents as superficial lesions along the deep plantar aponeurosis, which typically blends with the adjacent plantar musculature. Linear tails of extension (“fascial tail sign”) along the aponeurosis are frequent.

Plantar fibromas typically arise along the medial and central aspects of the plantar fascia, most often in non-weight-bearing areas. They often present as painful, firmly palpable masses along the plantar aspect of the foot. Bilateral involvement is seen in 20-50% of patients, and these lesions are thought to never metastasize. Other types of superficial fibromatosis, such as Peyronie disease and Dupuytren’s contracture, are associated with fibromas in 10-65% of cases; infiltration of soft tissue masses. It shows the local lesion as a hyperechoic mass, and is an inexpensive and accurate modality for diagnosis of fibromatosis. In a study by Griffith et al., twenty-five fibromatosis nodules in 19 patients, and these lesions are thought to never metastasize. Other types of superficial fibromatosis, such as Peyronie disease and Dupuytren’s contracture, are associated with fibromas in 10-65% of cases; infiltration of adjacent musculature is characteristic of deep or aggressive fibromatosis.

Bilateral involvement is seen in 20-50% of patients, and these lesions are thought to never metastasize. Other types of superficial fibromatosis, such as Peyronie disease and Dupuytren’s contracture, are associated with fibromas in 10-65% of cases; infiltration of adjacent musculature is characteristic of deep or aggressive fibromatosis.

Plantar fibromatosis typically arise along the medial and central aspects of the plantar fascia, most often in non-weight-bearing areas. They often present as painful, firmly palpable masses along the plantar aspect of the foot. Bilateral involvement is seen in 20-50% of patients, and these lesions are thought to never metastasize. Other types of superficial fibromatosis, such as Peyronie disease and Dupuytren’s contracture, are associated with fibromas in 10-65% of cases; infiltration of adjacent musculature is characteristic of deep or aggressive fibromatosis.

Computed Tomography
CT scans may be used to evaluate soft tissue masses within or arising from cortical bone. CT scans can also aid in determining the size of the mass and the association or relationship with surrounding structures. The problem with CT imaging for soft tissue masses such as plantar fibromatosis, is the CT scan will show a mass that resembles muscle and is therefore typically not diagnostic.

Magnetic Resonance Imaging
The gold standard imaging modality for soft tissue lesions is the MRI. Fibromas classically appear as intermediate to low signal intensity masses on T1 and T2 weighted images. This difference in MRI signal intensity is important because more cellular lesions have a higher local recurrence rate after excision. Thus, these lesions could be managed by follow-up MRI imaging to assess for change to lower signal intensity as an indication of maturation and decreased cellularity and to direct the optimal time for surgical intervention.

TREATMENT OF LEDDERHOSE SYNDROME VS DUPUYTRENS
Non-surgical Treatment of Ledderhose Syndrome
The most common nonsurgical treatments for Ledderhose include treatments mentioned previously such as shoe modifications, orthotics, steroid injections, stretching, anti-inflammatory medications and shockwave therapy.

Shockwave treatment
In a 2012 study to determine if extracorporeal shockwave therapy (ESWT) would decrease the pain from plantar fibromatosis, Knobloch and Vogt tested six patients (5 males, 58±4 years) with plantar fibromatosis who complained of pain. Three patients were operated on previously and one had concomitant Dupuytren’s contracture. High-energy focused ESWT was applied (2000 impulses, 3 Hz, 1.24 mJ/mm2) in two sessions with seven days in between. Pain (0<10) was 6±2 at baseline, 2±1 after 14 days and 1±1 after 3 months. Softening of the nodules was noted by all patients along with no adverse effects.

Cryotherapy
According to Terry L. Spilken’s book, Cryotherapy and Other Therapeutical Options for Plantar Fibromatosis. Dupuytren’s Disease and Related Hyperproliferative
Disorders, cryosurgery is an ambulatory procedure done in the doctor’s office. It involves freezing of nerve cells performed through a small incision. An autoimmune response is created with a change in the protein antigenic properties. There is about an 80% success rate when the fibromas are in the early stages. For advanced cases, the procedure is repeated several times until the desired effect of either decreased pain or softening of nodules is achieved.

**Radiotherapy**
The analyses thus far show surgery alone does not produce acceptable success rates as far as reoccurrence percentages are concerned. However, surgery supplemented with radiotherapy (RT) has been shown to be a viable option. Although effective in decreasing the recurrence rate, adjuvant radiotherapy should be used very selectively because of its serious side effects.

In a study of 158 patients (91 males, 67 females; mean age 49) with primary endpoints of prevention of progression (PP) and avoidance of surgery (AS) and secondary endpoints of number or size of nodules or cords, and symptom relief including pain relief, orthovoltage RT (125–150 kV X-rays) was used. RT was applied in 5 weekly fractions of gray unit repeated after a mean of 12 (range 10–15) weeks up to 30 Gy total doses. The outcome of the study found that external beam RT is the most effective treatment both for primary and recurrent Ledderhose as compared to all published surgical results. After long-term follow-up of at least 2 years, only 6 patients (with 11 feet, 8% total) had recurrent or progressive disease with only 5 patients (7 feet), 5% total requiring salvage surgery. As compared to surgical intervention, RT reaches a high and long-term remission rate, causes less side effects, is less impaired by relapses, and thus is highly cost-effective for the treatment and management of Ledderhose. There is no known cure for Ledderhose, but it appears that the application of RT may be the best care available for primary early stage. The potential role of RT for recurrent or progressive Ledderhose after completion of surgery is still to be determined.

**Collagenase**
Collagenase, in the form of recombinant tissue plasminogen activator (alteplase), has been used off label for Ledderhose. According to the International Dupuytren’s Society, patients have had success leading to return of function of affected tissue after one to two rounds of treatment.

**Topical Verapamil**
Verapamil is a calcium channel blocker used to treat hypertension and angina. Tropical verapamil: topical/transdermal verapamil hydrochloride 15% gel for Peyronie’s disease has been found to be successful in reducing pain and plaques and increasing flexibility. Peyronie’s disease is among this group of fibrous tissue diseases and although some initial research by the Association of Morbus Ledderhose with Dupuytren’s contracture as not found success for plantar fibromatosis, further research should be conducted.

**Surgical Treatment of Ledderhose Syndrome**
Even though a recovery with a non-invasive treatment is possible, certain severity of the lesion will demand a different approach. Surgical treatment is indicated in cases of persistent pain, large infiltrative lesions that cause significant disability, lesions that are refractory to non-operative management and if conservative measures fail. The standard procedure and the most functional surgery most recently, includes a partial fasciectomy of the plantar aponeurosis in order to release the tension. After partial resection, there is a high recurrence rate with an increased risk of complications and more aggressive in-growth into anatomical structures. Some authors recommend a complete fasciectomy as the primary procedure of choice. Postoperative radiotherapy can be used to diminish the chance of recurrence.

The standard surgical procedure for Ledderhose Syndrome is a partial fasciectomy of the plantar aponeurosis. However, after partial resection, there is a high recurrence rate with an increased risk of complications and more aggressive in-growth into anatomical structures. Partial or simple surgical excision can be associated with up to 60%-100% recurrence rates, and therefore wide marginal excision is often necessary also called subtotal plantar resection or fasciectomy. Some authors recommend a complete fasciectomy as the primary procedure of choice.

**Non-surgical Treatment of Dupuytren’s Disease**

**Collagenase injection**
Collagenase is used to break and release cords of Dupuytren’s disease. In 2010, the U.S. Food and Drug Administration approved Xiaflex® as the first drug to treat Dupuytren’s contracture, which can loosen the contracted tissue and potentially restore finger flexibility. Collagenase is directly injected into the contracted scar tissue that causes the Dupuytren’s contracture. Xiaflex® is an injectable formulation of purified collagenase clostridium histolyticum. An important ADR, especially in the foot, is tendon rupture.

**N-Acetyl-L-Cysteine (NAC)**
Dupuytren’s disease has been used as a model to study tissue fibrosis. Non-operative treatment options have been suggested involving radiation therapy, vitamin E, local injection therapy using calcium channel blockers,
Transforming growth factor-α1 (TGF-α1) and its downstream Smad signaling system is well established as a key player during fibrogenesis. Thus, targeting this basic pathomechanism seems suitable to establish new treatment strategies. One such treatment involves the substance N-acetyl-L-cysteine (NAC), shown to have antifibrotic properties in hepatic stellate cells and rat fibroblasts. Antifibrotic medication using a combination of NAC and ACE inhibitor can prevent the recurrence of Dupuytren’s disease. Given the fact that recurrence rate in Dupuytren’s disease is high and unpredictable after surgical release, an anti-fibrotic intervention might be worthwhile to consider in the clinical setting. Antifibrotic agents inhibit TGF-β1, which play a key role in fibromatosis. Thus, antifibrotic medication might reduce the recurrence rate in fibromatosis such as Dupuytren’s disease in a clinical significant way.

According to the International Dupuytren’s Society the above study is a laboratory study on Dupuytren’s cells, it was not a clinical study on patients. Yet this study indicates the possibility of NAC “providing a basis for a therapeutic strategy in Dupuytren’s disease and other fibroproliferative disorders.” Since publication of this study NAC has also been tested on patients (orally applied, typically 600 mg/day; private communication, not published).

Surgical Treatment of Dupuytren's Disease
When conservative treatments have failed, or the disease is in advanced states, surgery is the treatment of choice. This is also the case if function is impaired or if a contracture is progressive. Typically, surgical interventions are either a transection of cords (fasciotomy) or an excision of diseased fascial bands (fasciectomy). Surgery (partial or complete palmar fasciectomy) should be considered only when functional impairment is severe. The initial results are generally good, but the recurrence rate is high.

CONCLUSION
The goal of treatment for Ledderhose is based on stability while the goal of Dupuytren’s is more based on movement; stability of the feet and movement of the hands are important. Although the end goals are slightly different, the purpose of treatment can be the same, to decrease the signs and symptoms of the diseases which lead to pain in the foot and contracture and pain in the hand. Due to the high recurrence rate for plantar fibromas after a partial fasciectomy, it seems sensible to attempt utilizing existing treatments for Dupuytren’s disease such as collagenase (enzyme) injections, needling, and NAC. It is also imperative to continue to gather data for recent and ongoing plantar fibromatosis studies evaluating cryotherapy, topical/transdermal verapamil, and shockwave treatment. If conservative measures are unsuccessful in treating Ledderhose Syndrome, there is a promise in combining a plantar fasciectomy with radiotherapy for a lower recurrence rate.

Ledderhose Syndrome is typically a benign lesion of unknown origin. Pedal manifestations, can often be associated with additional local and systemic disorders and therefore should not be regarded as solely unique or isolated from other fibrous soft tissue masses. The symptomatic patient who does not respond to conservative care should be considered a surgical candidate. A wide excisional approach or subtotal plantar fasciectomy seem to offer the best prevention of lesion recurrence, based on prior research and surgical outcomes.

REFERENCE
A Review of the Symptomatic Os Vesalianum: An Uncommon Cause of Lateral Foot Pain

Olubukunola Oseni-Olalemi B.S., Sarah Strong-Adams B.B.A., Jessica Potter B.S., Tina Shahin B.A.

INTRODUCTION
An accessory ossicle is a secondary center of ossification due to an abnormal division of usual solitary centers. They may represent the failure of an ossification center to unite and they can develop from a secondary center. This secondary center may originate from the ossification center of the main bone, adjacent to, or separated from the main bone. Accessory ossicles may occur as subdivisions of normal bones or as a separate prominence of ordinary bone. They typically remain asymptomatic and are recognized as an incidental radiographic finding. However, there are instances where accessory ossicles present with pain. In this paper, we will review the os vesalianum, an accessory bone that has a low prevalence in the foot compared to other accessory ossicles.

The os vesalianum is an uncommon pedal accessory bone located lateral to the fifth metatarsal base. It may become symptomatic requiring surgical excision. The os vesalianum is often confused with a 5th metatarsal base avulsion fracture or a Jones fracture but it is often asymptomatic. However, it may present with tenderness over the 5th metatarsal base and radiographically present as an uncorticated sharp fracture line.

Os Vesalianum is located embedded in the peroneous brevis and located proximal to the fifth metatarsal. When symptomatic, the goal in diagnosis is to rule out an ossifying apophysitis of the fifth metatarsal base, an apophysitis of the fifth metatarsal base (Iselin’s disease), a fracture of the tuberosity of the fifth metatarsal, a nonunion of a tuberosity fracture of the fifth metatarsal, an un-united apophysis of the fifth metatarsal base, or an os peroneum. With a prevalence ranging from 0.1-5.9% in different research studies, it uncommonly leads to symptomatic lateral foot pain.

Figure 1.1 Os vesalianum. 1. Ossification within the apophysis of the fifth metatarsal base. 2. Fragmentation within the ossification of the fifth metatarsal apophysis. 3. Un-united apophysis of the fifth metatarsal base. 4. Position of the os vesalianum. Note different orientation of articulation. Reproduced with written permission from Dr. Ozkan Kose.

PHYSICAL EXAM
Although the presence of os vesalianum is typically asymptomatic, it may cause a variety of painful syndromes or may mimic pain similar to a fracture. The location of pain associated with the symptomatic os vesalianum upon physical examination will be proximal and adjacent to the base of the fifth metatarsal. It may be accompanied with tenderness upon palpation over the fifth metatarsal base resulting in lateral foot pain. Ankle and foot motion remain normal upon assessing range of motion. Dermatologic findings such as hyperkeratotic lesions are usually absent with symptomatic os vesalianum but edema, redness, and local heat may appear as present on the lateral margin of the fifth metatarsal base in some cases.

IMAGING
Radiographs serve as the primary imaging modality of symptomatic os vesalianum. Lateral oblique radiographs best demonstrate the ossicle and its articulation. A radiograph of the symptomatic foot will reveal...
a large accessory bone proximal to the fifth metatarsal base. A thin translucent line of constant width separates the ossicle from the metatarsal revealing an uncorticated sharp fracture line.4

Radiographic diagnosis may be difficult because the fifth metatarsal may be affected by various traumatic events. Jones fractures, stress fracture of the proximal fifth metatarsal, avulsion fracture of the fifth metatarsal, secondary center of ossification of the proximal fifth metatarsal, Iselin’s disease and malunion must all be considered in the radiographic differential diagnosis of os vesalianum.9

To differentiate from a fracture, bone scintigraphy may be used as an imagining modality. A CT scan may show rounded margins and cortication of bony fragments, which differentiates accessory bones from traumatic avulsions.5 Additionally, os vesalianum is surrounded by bony cortex, and the margins are rounded with possible articulation with adjacent cuboid bone further differentiating it from a fracture.10

Presentation on XRAY

TREATMENT
Symptomatic os vesalianum, may initially be treated with activity limitation, shoe inserts, physical therapy, corticosteroid injections and basic analgesics may be used to reduce pain.7,8 If symptoms can not be controlled with activity limitation, immobilization with a cast or splint has been reported to control the pain.5

Excision of the accessory bone has been reported as the primary surgical treatment used if conservative treatment fails. Inoue et al. describe two types of surgical procedures that are available for symptomatic cases where conservative measures of treatment are ineffective. Simple resection has been reported to give good results but if the ossicle is very large, attention should be given to the preservation of the peroneus brevis tendon. Osteosynthesis with bone grafting, usually performed for pseudoarthrosis, can be done as another treatment option. For large ossicles, screw fixation is recommended and for small ossicles, excision of the bone can be considered.7

SUMMARY OF CASE REPORTS
Dorrestin et al. present a case of a 25 year old woman that took place in 2009 illustrates the infrequency and difficulty in diagnosing os vesalianum, a causative factor of lateral foot pain. Four months prior to visiting the clinic, the patient kicked a box with the lateral side of her left foot. The initial radiographs were unremarkable whereas the second set showed a radiolucent line through the base of the fifth metatarsal at the point of tenderness suggesting a delayed union of a tuberosity fracture. However, the finding was bilateral, resulting in a symptomatic accessory bone to be included in the differential diagnosis. The practitioner placed the patient in a short-leg walking cast based on the findings.

The patient’s one month follow-up showed identical radiographic images and unchanged perception of pain. The walking cast was continued for an additional 5 weeks. The 2 month follow-up revealed extreme pain, this time on the right foot when walking on uneven surfaces. At this time bilateral avulsion fractures seemed unlikely and the diagnosis of bilateral symptomatic accessory bones was confirmed through computed tomography (CT) and bone scintigraphy. The CT

Figure 2: (a) Lateral oblique radiograph of a 37-year old man with an inversion ankle injury. Avulsion fracture of the fifth metatarsal base is seen (arrow). (b) Forty-two-year-old woman with fore-foot pain. The incidental accessory bone, os vesalianum (arrow), was considered unrelated to the patient’s complaint. Note the well corticated appearance and clear articulation with adjacent cuboid. (c) Fifty-seven-year-old man, a heavy smoker, with a history of acute fracture two years previously, oblique radiograph demonstrates a non-union of the fifth metatarsal base (arrow). Reproduced with written permission to use from Dr. Ozkan Kose.
showed rounded margins and cortication of both bony fragments, which can differentiate an accessory bone from a fracture. The bone scintigraphy showed increased uptake bilaterally further confirming the diagnosis of an accessory ossicle. In general, fractures have sharp radiolucent lines fitting well to the adjacent bone in irregular geometry with an uncorticated margin whereas accessory ossicles and sesamoid bones usually have well defined cortical margins and are rounded and oval shaped.

Once proper diagnosis of bilateral vesalianum was established, the patient was treated with surgical excision of the accessory bone on the patient’s right foot. Despite complete sensory loss on the lateral side of her foot due to assumed neurotmesis of a branch of the sural nerve during surgery, the patient reported a decrease in pain and was satisfied with the procedure.

Inoue et al. report a case of a 13 year old girl with symptomatic os vesalianum who underwent various conservative and surgical treatments to relieve her symptoms. The onset of lateral foot pain in this patient began at 13 years of age while playing volleyball and walking. She presented with no history of trauma or strain bilaterally. After 4 months from the onset of pain, her physical exam revealed swelling, tenderness and local heat on the lateral aspect of both feet near the 5th metatarsal base. Plain radiographs revealed an osseous line that was well defined and corticated at the base of each fifth metatarsal. A thin translucent line separated the ossicle from the metatarsal with sclerotic opposing surfaces on the base of the 5th metatarsal.

The 13 year patient received conservative treatment which began with shoe inserts that provided support to the arches. This method provided only moderate relief. The patient returned to most normal activity but was unable to take part in volleyball due to the regression of her painful symptoms. Surgical management of this patient was the next option as conservative measures were not successful. As the right foot was more symptomatic for the patient, surgery was first performed on this side. The surgical method used was osteosynthesis with bone grafting from the iliac wing. During surgery, it was found that most of the fibers of the peroneus brevis tendon inserted into the accessory ossicle and the ossicle articulated with the metatarsal anteromedially but moved independently of the metatarsal at the junction. Partial resection of the bone and fibrous tissue from the ossicle was performed and the defect was filled with a bone graft from the iliac wing. The exact size of the screw was not reported in the case, but it noted that a small cannulated screw was used to fixate the ossicle to the metatarsal.

The patient was non weight-bearing in a short leg cast for six weeks postoperatively and full weight-bearing at eight weeks postoperatively. She refused to undergo surgery for the left foot as it was non-symptomatic during activity. After a two year follow up, the epiphyses of all the metatarsals and phalanges were closed with adequate fusion of the right fifth metatarsal with asymptomatic results. The ossicle of the left foot still showed separation from the fifth metatarsal with symptomatic lateral foot pain. In this specific case surgery provided better end results for the patient as compared to conservative methods.

Wilson et al. report a case of a healthy 24 year old female presenting with chronic pain of her fifth metatarsal base that had started 3 months prior. The patient denied any trauma and stated the pain was most intense after prolonged standing. Localized pain to the lateral fifth metatarsal base with slight edema was found during physical examination. A plain radiograph of the skeletally mature foot showed a large accessory bone located proximal to the fifth metatarsal base with a lucent line of constant width separating the ossicle from the metatarsal bone, resulting in a diagnosis of painful os vesalianum.

The patient was initially treated with a palpation guided corticosteroid injection and activity modification. The injections gave the patient no relief so two additional corticosteroid injections were given in the area of maximum tenderness for the next month. After failure to resolve the pain with steroid injections, the patient underwent 4 weeks of physical therapy utilizing ultrasound, electrical stimulation, stretching, and exercises twice weekly. Physical therapy also failed to improve the patient’s pain, thus surgical treatment was recommended for symptomatic relief.

Surgical treatment consisted of simple excision with tenorrhaphy because the ossicle was well contained within the peroneus brevis tendon. It was noted that the os vesalianum articulated with the fifth metatarsal but not the cuboid and was attached to 5% of peroneus brevis fibers. Post operatively, the patient remained non-weight-bearing on crutches for 3 weeks. After week 4, the patient was allowed to weight-bear with a surgical shoe and progressed to normal shoe-gear and activity by week 5. At the 5 week mark, the patient had full range of motion and strength of the peroneus brevis tendon when compared to the contralateral foot.

Boya et al. report symptomatic os vesalianum pedis in a 22 year old man with the complaint of pain in the right foot and ankle with mild swelling of the fifth metatarsal after an inversion injury of the right foot. Anteroposterior, lateral and oblique plain radiographs were taken showing an ossicle at the base of the fifth metatarsal. Similar to previous cases, there was a thin radiolucent line of constant width and a distinct articulation between the ossicle and the cuboid bone.
Conservative treatment consisting of rest, application of an elastic bandage and nonsteroidal anti-inflammatory medication was followed. The patient was asymptomatic at the follow up visit 2 weeks later and remained asymptomatic at 1 year. In this specific case study, the patient was asymptomatic until an inversion injury took place thereby having the traumatic event initiating a symptomatic os vesalianum. Conservative treatment remained successful in this case.

CONCLUSION
Symptomatic accessory bones of the ankle and foot are considered skeletal variations. Occurrence of os vesalianum is rare with males and females being equally affected. Bilateral incidence is seen in 7.6% of cases reported, but can be seen in up to 25% of the general population.

Misdiagnosis of os vesalianum is common; os vesalianum should be differentiated from fifth metatarsal avulsion fractures, ossification of the fifth metatarsal base apophysis, apophysitis of the fifth metatarsal base (Iselin’s disease), fractures of the tuberosity of the fifth metatarsal, non-unions, un-united apophysis of the fifth metatarsal base, and os peroneum. This distinction can be made by utilizing the following characteristics: 1) a fracture of the apophysis or base of the fifth metatarsal is transverse in direction; 2) the ossification center of the apophysis is initially linear and oriented longitudinal and parallel to the metatarsal shaft; 3) an os vesalianum is located just proximal to the tip of a well-developed fifth metatarsal tuberosity; and 4) with an os vesalianum, the opposing surfaces may be sclerotic and denote a chronic condition. Os vesalianum pedis is surrounded by bony cortex and the margins are rounded. Articulation with the adjacent cuboid bone can also occur.

Treatment for os vesalianum should begin conservatively with rest, limited weight bearing, casting, and shoe inserts. If these treatments fail to completely resolve symptoms, as seen in all three cases, surgical treatment should be considered. Surgical excision of the accessory bone must be executed properly in order to preserve the peroneus brevis tendon and its insertion. Osteosynthesis and bone grafting has also been successful in providing symptomatic relief when conservative treatments have failed.

REFERENCES