Vascular Disruption of the Talus: Comparison of Two Approaches for Triple Arthrodesis.

INTRODUCTION

Adequate blood supply to the talus is an important consideration for successful fusion following a triple arthrodesis.\(^1,2\) Damage to the main arterial supply of the talus, which includes the artery of the tarsal canal, deltoid artery, and artery of the tarsal sinus, may occur during such procedure.\(^3\) Disruption to one or more of these arteries could compromise blood supply and result in complications such as nonunion or even avascular necrosis (AVN).\(^4-6\) Therefore, in addition to adequate joint surface preparation, preservation of blood supply to the osseous framework is essential for effective fusion and to reduce the likelihood of other complications. Occasionally triple arthrodesis is combined either concomitantly or as consecutive surgeries with a total ankle replacement for alignment correction of the hindfoot.\(^7,8\) Avascular necrosis, or a decrease in blood supply to the talus, can result in failure of the joint replacement and is a contraindication to the procedure.\(^9\)

Triple arthrodesis commonly involves a combined medial and lateral incision, which is thought to allow the best access to the talonavicular, subtalar, and calcaneocuboid joints for debridement and preparation.\(^10,11\) While this approach is widely accepted, lateral incision complications such as difficult wound healing can occur especially in cases with severe pes planus deformity causing contracture of the lateral soft tissue.\(^12-17\) This has encouraged some surgeons to prepare all joints with a single medial incision when indicated, thus avoiding the lateral wound.\(^12,18-20\) The change in the operative approach for triple arthrodesis could influence the effectiveness of joint preparation and/or the degree of damage to the blood supply of the talus.
The purpose of this study is to compare the two approaches, single-medial-incision vs. two-incision, for the triple arthrodesis in regard to the disruption of blood supply to the talus using pre and postoperative CT angiography guided dissection. A comparison of joint preparation between the two approaches will also be evaluated.

METHODS

Fourteen un-embalmed cadaveric lower limb specimens without an obvious deformity or any evidence of prior surgery were used to demonstrate disruption of peritalar arterial supply coupled with an operative approach. Seven paired limbs were used. Average age of the specimens was 82 years (range 51 – 94 years). Specimens were blindly assigned to an operative approach using a random number table: seven legs were assigned to the single-medial-incision approach and seven were assigned to the two-incision approach.

The arterial vasculature of each limb was investigated after injections of barium sulfate and latex suspension into the posterior tibial, anterior tibial, and peroneal arteries with an 18-gauge needle coupled to a 30 mL syringe. A small skin incision was made in the first web space at the level of the metatarsophalangeal joints. This incision provided access for visualization of the latex suspension to ensure penetration to the distal vessels in the foot. Each leg was imaged preoperatively using a high-resolution, 3D computed tomography scanner. For imaging, each limb was placed in a support frame with the ankle at neutral position and scanned at one-millimeter sections from the plantar surface through mid-tibia. Post-scan analysis and 3D reconstruction were completed using Osirix (Pixmeo SARL, Switzerland). Peritalar arterial patterning was observed and recorded.

All operative procedures were completed by a fellowship-trained, orthopaedic surgeon (PP). For the single-medial-incision approach, a single medial incision was used for all joint
preparation (Figure 1). A straight longitudinal incision was made starting from the tip of the medial malleolus towards the center of the naviculocuneiform joint medially. Subcutaneous tissue was incised sharply along the incision. The tibialis posterior tendon sheath was open and the tendon was retracted posteriorly. Sharp dissection was then carried along the medial aspect of the talonavicular joint towards the palpable middle and posterior facets of the subtalar joint. The interosseous ligament was released and a Hintermann distractor was used to distract the subtalar and talonavicular joints. The joint debridement was accomplished using curettes and osteotomes, while preserving the subchondral bone. The calcaneocuboid joint was then debrided using the same technique through the distracted talonavicular interval.

For the two-incision approach, a curvilinear incision was made beginning from the posterior aspect of the tip of the lateral malleolus towards the anterior process of the calcaneus, and then curved to the base of the fourth tarsometatarsal joint (Figure 2). Subcutaneous tissue was incised sharply along the incision. The extensor digitorum brevis muscle was then incised and retracted medially. The inferior extensor retinaculum, the cervical, and the interosseous talocalcaneal ligaments were sharply released. With distraction provided by the Hintermann distractor, cartilage from the subtalar and the lateral part of the talonavicular joints was debrided using curettes and osteotomes, while preserving the subchondral bone. The calcaneocuboid joint was directly identified and the capsule was excised. The joint was distracted and debrided in the same fashion. The medial part of the talonavicular joint was distracted and debrided through a separated four-centimeter incision just lateral to the tibialis anterior tendon.

Post-surgery, the legs were again imaged using a CT scanner and analyzed using 3D reconstruction techniques to determine disruptions of peritalar arterial branches as compared to the pre-surgery images. Following postoperative imaging, each leg underwent guided dissection
aided by the CT reconstructions and loupe magnification (x3.5). Dissection of main arteries and their branches known to supply the talus proceeded in a proximal to distal direction. The latex dye further assisted in detection of vascular disruptions and allowed more accurate observation of the vascular patterning. An experienced anatomist (MP), who was not directly involved in the operative procedure, reviewed and confirmed all vascular disruptions.

The debridement of the articular surfaces of the talus, calcaneus, navicular, and cuboid were analyzed using a translucent-film mapping technique.\(^{21}\) While the joints were stabilized in neutral position using K-wires the articulating joint surfaces were outlined with marker and cleared of any remaining tissue. Each joint surface and the remaining articular cartilage was outlined and traced using semi-transparent paper. The mapping of each articular surface was scanned and the total surface area and area of remaining articular cartilage were calculated using image-analysis software, Image-J (Wayne Rasband, National Institutes of Health, Bethesda, MD). Two members of the research team (JH and TV), who were not directly involved during the operative procedure, completed and analyzed the mapping.

The frequency of each arterial injury was compared between the two approaches using Fisher’s exact test. The area of joint preparation from each technique was also analyzed and compared using a paired t-test. A p-value of less than 0.05 was used for statistical significance.

RESULTS

Analysis of the articular surfaces joint preparation (Table 1) showed that, with the number of specimens available, there was no significant difference in the mean percentage of joint debridement for the talonavicular and subtalar joints, when comparing single-medial-incision and two-incision approaches respectively. There was also no difference when each facet of the subtalar joint was compared separately. However, there was a significant difference
between the two approaches when comparing the joint preparation at the calcaneocuboid joint. The two-incision approach accomplished more complete joint debridement at the calcaneocuboid joint compared to the single-medial-incision approach.

Postoperative, CT angiogram guided, dissection revealed that both approaches caused damage to one or more of the three main arteries supplying the talus (Table 2). The single-medial-incision approach was found to consistently damage both the deltoid artery and the artery of the tarsal canal in most specimens (86% and 100%, respectively), while the artery of the tarsal sinus was always disrupted (100%) by the two-incision approach. The frequencies of arterial disruption for all the three main branches were significantly different between approaches (all p<0.01). Other arteries that were occasionally injured in the two-incision approach were proximal branches of the dorsalis pedis that supply the head of the talus including the lateral talar artery and the medial talar artery. The medial recurrent artery was damaged in all specimens regardless of their assigned approach. There was no significant difference in the frequency of disruption of the lateral branches, including lateral tarsal artery, anterior lateral malleolar artery, and posterior recurrent lateral talar artery with the number of specimens available.

**DISCUSSION**

We have found that potential substantial damage could occur to the peritalar arterial blood supply from either single-medial-incision or two-incision approach used for triple arthrodesis. The peritalar vascular map as outlined by Mulfinger and Trueta\(^2\) in 1970 and by Gelberman and Mortenson\(^3\) in 1983 clearly described the contributions of both extraosseous and intraosseous vessels to the talus. These primary vessels include the artery of the tarsal canal, artery of the tarsal sinus, and the deltoid artery (Figure 3). Using this information, the combined damage to the artery of the tarsal canal and the deltoid artery that consistently occurred from the
single-medial-incision approach may theoretically reduce blood flow to 3/4 of the talar body (middle 1/2 and medial 1/4), assuming similar arterial pressures and distribution. The damage to the artery of the tarsal sinus that consistently occurred from the two-incision approach could theoretically reduce blood supply to the lateral 1/4 of the talar body and the inferior lateral 1/3 of the talar head. Concerning the integrity of the talar body, the two-incision approach appeared to cause less arterial disruption to the area. While the interpretation of vascular disruption to the talus from Gelberman and Mortenson’s model clearly favored the two-incision approach, the resulting damage to other contributing arterial branches has not been well studied. A recent study by Miller et al demonstrated the presence a rich anastomotic network of arterial supply to the talus both intraosseously and extraosseously.\textsuperscript{23} A reduction in blood supply to the talus by disrupting arterial branches over a certain threshold may increase the risk of avascular necrosis similar to the phenomenon observed in a displaced talar neck fracture.\textsuperscript{3-6,24,25}

Avascular necrosis of the talus is a recognized complication after a triple arthrodesis with reported incidence up to 17 percent.\textsuperscript{2,4,26-29} Vascular disruption from the surgery, extensive bone resection, periosteal stripping, placement of screw fixation, previous surgeries, associated injuries, steroid use, and certain underlying diseases (e.g. Friedreich’s ataxia) have been hypothesized as associated factors. Pain and disability in patients with collapsed talar dome often necessitated a conversion to pan-talar arthrodesis or required a long-term ankle-foot orthosis.\textsuperscript{4,25,29} As observed in the current study, triple arthrodesis can result in major disruption to arterial branches along the path of dissection and joint preparation and as such necessitates considering vascular sparing when selecting an appropriate operative approach. For example, in patients with a history of previous surgery, an approach utilizing the same incision without disturbing the intact part of the vascular network is preferred. Further studies may determine
whether pre-operative CT-angiography may provide useful information regarding the degree and location of preserved peritalar arterial branches.

We have found that both operative approaches could allow effective debridement of the subtalar and talonavicular joints. The calcaneocuboid joint preparation was superior in the two-incision approach. This is in contrast to a cadaveric study by Jeng et al \textsuperscript{12} that demonstrated no difference in the effectiveness of joint preparation of all talonavicular, subtalar, and calcaneocuboid joints for the two approaches. Several aspects of our protocol that were different from Jeng et al. included preservation of the tibialis posterior tendon and the inferolateral part of the spring ligament, preservation of subchondral bone integrity, the use of translucent-film technique for joint debridement analysis, and the use of independent evaluators. While its consequences have not been well studied, a complete release of the spring ligament and the posterior tibial tendon will likely improve the exposure to this joint. We believe the calcaneocuboid joint is difficult to access from the single-medial-incision approach due to the curvature of the joint surfaces and the difficulty of accessing the joint from across the foot through the talonavicular joint. Due to these obstacles, it may be beneficial to add a small incision directly over the lateral aspect of the calcaneocuboid joint away from the sinus tarsi exclusively for preparation of the this joint. This would allow for minimal dissection on the lateral aspect to avoid wound problems yet still allow for successful preparation of the calcaneocuboid joint. In the absence of arthritis of the calcaneocuboid joint, several authors recommended using a single medial approach for the preparation of only the talonavicular and subtalar joints to eliminate the lateral wound altogether and to limit dissection and operative time.\textsuperscript{30-32} Fixation of only the talonavicular and subtalar joints has been shown to correct
hindfoot deformities as effectively as the triple arthrodesis in both cadaveric and clinical studies.\textsuperscript{12,19,31,33,34}

This study has limitations due to the use of specimens from donors with an average age of 82 years. The relative stiffness of the specimens and the inadequate soft tissue release may have made the exposure more difficult although all of them were free of obvious arthritic changes. We also could not define the contribution of vascular disruption from other vascular branches other than those described by Gelberman and Mortensen.\textsuperscript{3} Further cadaveric studies using gadolinium-enhanced magnetic resonance imaging on triple arthrodesis with or without concomitant anterior approach for the total ankle replacement are recommended.\textsuperscript{23} Ideally, in vivo studies applying laser doppler probes for the measurement of talar blood flow might also prove useful.\textsuperscript{35}

In conclusion, substantial damage can occur to the peritalar arterial blood supply from both single-medial-incision and two-incision approaches for a triple arthrodesis. The single-medial-incision approach consistently disrupted the majority of blood supply to the talar body, while the two-incision approach caused various degrees of vascular disruption to the talar head and neck. Using the single-medial-incision approach, the calcaneocuboid joint did not show adequate removal of articular cartilage due to difficulties accessing the joint surfaces from the medial aspect across the foot. Vascular sparing to the talus should be considered when selecting an appropriate operative approach for triple arthrodesis. Although the incisions for a total ankle replacement were not evaluated, this cadaveric study infers the preference of the two-incision approach when a total ankle replacement is contemplated or concomitantly performed due to the potentially lesser degree of vascular disruption to the talar body.
REFERENCES


FIGURES

Figure 1: The picture demonstrates outline of the skin incision for the single-medial-incision approach on a right foot.

Figure 2: The picture demonstrates outline of the skin incisions for the two-incision approach on a right foot.

Figure 3: Intraosseous blood supply of the talus is demonstrated. The medial 1/4, the middle 1/2, and the lateral 1/4 of the talar body are supplied by the deltoid artery, the artery of the tarsal canal, and the artery of the tarsal sinus, respectively. The superomedial 2/3 of the talar head is supplied by the superior neck vessels while the inferolateral 1/3 is supplied by the artery of the tarsal sinus. Adapted from Gelberman et al.⁰¹²
**TABLE 1:** Percentage of Joint Debridement

<table>
<thead>
<tr>
<th>Joint</th>
<th>Mean Percentage of Debridement</th>
<th>SMI</th>
<th>TTI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talonavicular</td>
<td>73.7%</td>
<td>73.7%</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Calcaneocuboid</td>
<td>36.5%</td>
<td>84.9%</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Subtalar</td>
<td>79.6%</td>
<td>74.2%</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>82.6%</td>
<td>66.0%</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>78.3%</td>
<td>50.5%</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>79.7%</td>
<td>82.3%</td>
<td>0.22</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2:** Summary of arterial disruption between approaches

<table>
<thead>
<tr>
<th>Artery</th>
<th>Presence of Artery</th>
<th>Rate of injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoid artery</td>
<td>100%</td>
<td>86% 0%</td>
</tr>
<tr>
<td>Artery of the tarsal canal</td>
<td>100%</td>
<td>100% 0%</td>
</tr>
<tr>
<td>Artery of the tarsal sinus</td>
<td>100%</td>
<td>0% 100%</td>
</tr>
<tr>
<td>Lateral Talar artery</td>
<td>100%</td>
<td>0% 14%</td>
</tr>
<tr>
<td>Lateral Tarsal artery</td>
<td>93%</td>
<td>0% 29%</td>
</tr>
<tr>
<td>Posterior recurrent branch of lateral tarsal artery</td>
<td>86%</td>
<td>83% 100%</td>
</tr>
<tr>
<td>Perforating peroneal artery</td>
<td>100%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>Anterior lateral malleolar artery</td>
<td>86%</td>
<td>0% 17%</td>
</tr>
<tr>
<td>Medial recurrent tarsal artery</td>
<td>100%</td>
<td>100% 100%</td>
</tr>
<tr>
<td>Medial talar artery</td>
<td>93%</td>
<td>0% 43%</td>
</tr>
<tr>
<td>Posterior tubercle artery</td>
<td>86%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>Posterior branch of peroneal artery</td>
<td>100%</td>
<td>0% 0%</td>
</tr>
</tbody>
</table>