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Original Research

Assessment of Medial and Lateral Neurovascular Structures after Percutaneous Posterior Calcaneal Displacement Osteotomy: A Cadaver Study

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ABSTRACT

A prospective investigation of the effects on the medial and lateral neurovascular structures of the rearfoot after percutaneous posterior calcaneal displacement osteotomy was performed using 20 below the knee fresh frozen cadaver specimens. This anatomic study aimed to examine the medial and lateral neurovascular structures to determine whether they were jeopardized during execution of the osteotomy. After completion of the osteotomy, the medial plantar, lateral plantar, medial calcaneal, sural, and posterior tibial neurovascular structures, along with their respective branches, were inspected for iatrogenic injury. Our findings demonstrated that the percutaneous, subperiosteal osteotomy minimized trauma to the local soft tissue envelope and protected the adjacent neurovascular structures. Because no iatrogenic injury was observed in the cadaveric specimens, we postulated that percutaneous calcaneal displacement osteotomy is a safe, predictable, and advantageous alternative compared with open techniques for osteotomy and could result in reduced postoperative complications. The results of this investigation remain to be confirmed in the clinical setting.

Calcaneal displacement osteotomies have historically been used to correct the valgus deformity of the calcaneus seen with flexible pes planovalgus deformities, rearfoot varus deformities, frontal plane deformities, sagittal plane deformities, and posterior calcaneal fractures (1). Typically, when treating posterior tibial tendon dysfunction, particularly with Johnson and Strom late stage II and stage III deformities (2–4), the medial calcaneal displacement osteotomy (MCDO) has proved to be a valuable procedure because it might obviate the need for a triple arthrodesis and structurally realigns the foot (5). The complications noted when using the standard lateral approach of a calcaneal displacement osteotomy include wound dehiscence, sural nerve damage, sural neuritis, delayed union, nonunion, infection, and invasion of the medial neurovascular structures (6–11). The soft tissue layer on the lateral calcaneus presents a potential problem of wound dehiscence when performing open MCDO. Large incisions on the lateral aspect of the foot can also cause fibrosis in the area, leading to painful nerve symptoms. When performing open MCDO, the surgeon must be vigilant about exiting the medial aspect too aggressively because of the neurovascular structures that lie in this area (6,11).

Financial Disclosure: None reported.
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Numerous anatomic structures are at risk when performing MCDO, specifically the medial plantar nerve, lateral plantar nerve, medial calcaneal nerve, sural nerve, and posterior tibial arterial and venous structures. Our study examined these neurovascular structures of the rearfoot after percutaneous posterior calcaneal displacement osteotomy (PPCDO). Because this study was done through the authors' private practices, no institutional review board approval was sought.

Materials and Methods

A PPCDO was performed by the primary investigators (L.A.D. and J.A.) on 20 fresh frozen cadaveric below the knee limbs using a no. 15 scalpel, a flexible gigli saw and handles, a small curved hemostat, a straight hemostat, a tonsil hemostat, a ¼-in. osteotome, and wire cutters (Fig. 1). The first stab incision was made full thickness at the inferior, posteromedial calcaneal tubercle along the lines of the proposed osteotomy. A curved mosquito hemostat was then bluntly deepened to the cortical wall of the calcaneus. Using the curved end of the hemostat, which was held firmly against the bone, a subperiosteal tunnel was created toward the superomedial aspect of the calcaneus. It was essential that the tip of the hemostat be directly over the calcaneus to bluntly create a tunnel deep to the neurovascular structures. After reaching the superomedial landmark, the skin was tented, and a second stab incision was made parallel to the resting skin tension lines. The curved mosquito hemostat was then removed and a curved tonsil hemostat inserted into the tunnel site. The tip of the curved tonsil hemostat was then manipulated such that it exited the superomedial incision site, where a 12-in. flexible gigli saw was introduced. The tonsil hemostat was then pulled inferiorly through the tunnel of the inferomedial incision, thereby leaving 1 loop of the gigli saw protruding from the incision. The tonsil hemostat, which is long

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Fig. 1. Instrumentation used to dissect cadaver limbs included no. 15 blade and Bard-Barker handle®, flexible gigli saw and handles, small curved hemostat, straight hemostat, tonsil hemostat, ¼-in. osteotome, and wire cutters.

and unlikely to apply excessive stress on the surrounding tissues when the looped end of the gigli saw was inserted into its jaws, was then unclamped from the end of the saw.

Attention was then redirected to the superomedial incision, which was localized in Kager's triangle anterior to the Achilles tendon and posterior to the posterior facet of the calcaneus. With attention directed at ensuring firm placement along the superior aspect of the calcaneus, a straight hemostat was used to create a second subperiosteal tunnel. The skin was tented at the superolateral aspect of the calcaneus, anterior to the Achilles tendon, posterior to the peroneal tendon, and posterior to where one would most commonly find the sural nerve. A third stab incision was then made in the superolateral aspect of the calcaneus parallel to the relaxed skin tension lines. The hemostat was then removed from the superomedial incision site, and a straight hemostat was introduced through the superolateral incision and directed medially, following the second subperiosteal tunnel and exiting the superomedial incision. The tip of the hemostat was then opened, and the free end of the gigli saw placed into the tip of the straight hemostat. The hemostat was clamped on the saw and pulled back through the tunnel; exiting the superolateral incision and pulling the gigli saw through the incision, after which the hemostat was unclamped.

A fourth stab incision was then made at the inferolateral aspect of the calcaneus along the lines of the proposed osteotomy and opposite the inferomedial incision. The incision was bluntly deepened to the cortical wall of the calcaneal body with a curved hemostat, and a subperiosteal tunnel, running deep to the neurovascular structures, was created superiorly toward the superolateral incision, again being sure to keep the tip of the hemostat firmly against the body of the calcaneus. The curved hemostat was then removed from the wound, and the curved tonsil hemostat was inserted into the tunnel and directed so that it exited the superior incision at the lateral aspect of the calcaneus. The free end of the gigli saw was again inserted into the tip of the hemostat and pulled back through the tunnel so that it exited the inferolateral incision. The tonsil hemostat was released, and the gigli saw handles were linked on the medial and lateral aspects of the foot. The gigli saw was then pulled taut, taking care not to kink the saw, allowing for equal amounts of blade to exit each of the inferior incisions. The position of the gigli saw was deep to all neurovascular structures, across the superior aspect of the body of the calcaneus, and along the medial and lateral cortical walls of the calcaneus. Using image intensification fluoroscopy, a lateral radiographic view of the foot was then taken to ensure proper placement of the saw at the posterior aspect of the calcaneus and to ensure no kinks were present in the gigli saw (Fig. 2).

The placement of the incisions is imperative to ensuring that the osteotomy is performed in the proper plane, inclined posteriorly at approximately 45° to the plantar surface of the rearfoot. A surgical assistant stabilizes the lower leg and dorsiflexes the foot, thereby tightening the plantar fascia and Achilles tendon when the osteotomy is being executed. Furthermore, dorsiflexion of the digits and ankle dynamically stabilizes the soft tissues, in addition to physically stabilizing the foot and ankle when the osteotomy is made. As the gigli saw advances through the calcaneus, the surgeon must widen their arms to avoid harming the plantar soft tissues as the cut propagates from dorsal to plantar through the body of the calcaneus. As the surgeon advances toward the plantar aspect of the calcaneus, extreme care must be taken to avoid exiting the calcaneus forcefully, which could injure vital plantar structures. At this time, a lateral radiographic view was used to confirm that the saw was nearing the plantar cortex (Fig. 3). Once the osteotomy was completed, the medial portion of the gigli saw was cut as close to the skin as possible and the medial segment removed, after which the remaining piece of the gigli saw was pulled through the lateral

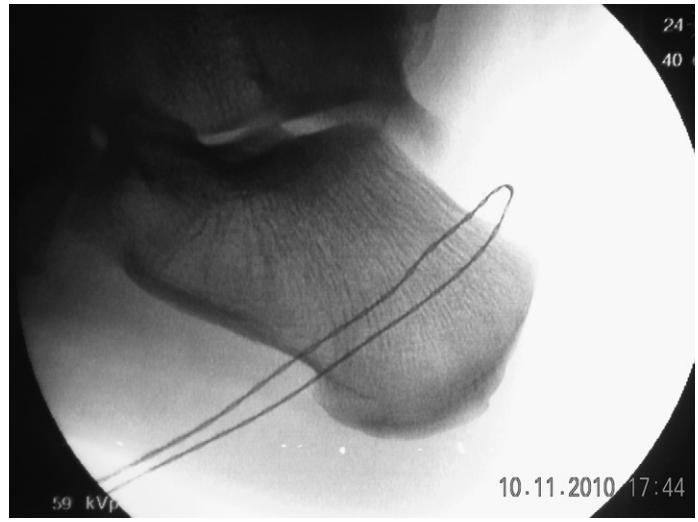

Fig. 2. Under fluoroscopy, lateral view of foot taken to ensure proper placement of gigli saw at posterior aspect of calcaneus, with no kinks visualized.

incision, thereby minimizing the amount of gigli saw being pulled through preserved soft tissue.

After completion of the osteotomy, the assistant plantarflexed the ankle and toes in an effort to destabilize the soft tissue dynamization and displacement of the posterior portion of the calcaneus into the desired position. It is essential to plantarflex the ankle and toes such that the plantar fascia and Achilles tendon are loosened (relaxed), thereby enabling the surgeon to maneuver the posterior aspect of the calcaneus into the desired position with very little resistance. Once the correction was achieved, the ankle and toes were again dorsiflexed to restore the soft tissue tension, which was used to recreate the dynamic stabilization until internal fixation was placed in the osteotomized calcaneus. An axial calcaneal radiograph was used to ensure that appropriate displacement had been achieved (Fig. 4). Once the degree of correction was ascertained, 2 guidewires from the large cannulated cancellous screw set were placed perpendicularly to the osteotomy, through the posteroplantar aspect of the foot. With fluoroscopic guidance, the wire placement was checked using the lateral and calcaneal axial views. After adequate wire placement, interfragmental compression (lag technique) screws of the appropriate length were inserted (Fig. 5).

After performance of each surgical procedure, careful and thorough dissection was performed on the medial and lateral aspect of each cadaveric specimen by residents

Fig. 3. Additional lateral view demonstrating gigli saw approaching plantar cortex.

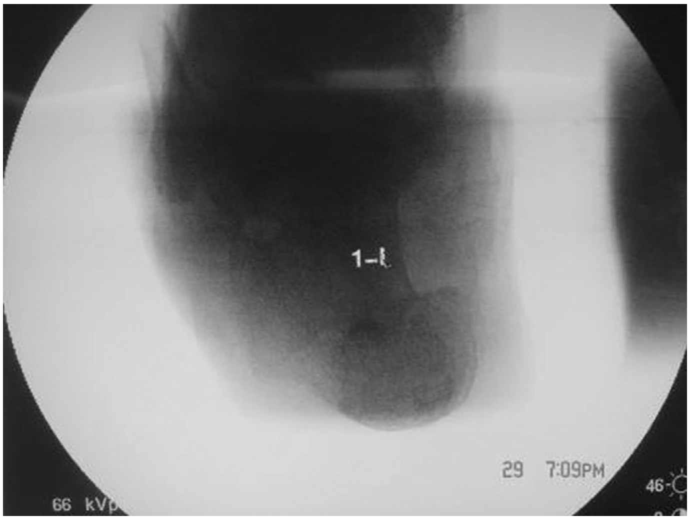

Fig. 4. Calcaneal axial radiograph showing displacement of posterior calcaneus displaced medially.

and a fellow, and the respective neurovascular structures were isolated proximal and distal to the surgical site and inspected for any gross evidence of iatrogenic injury (L.A.D. and J.A.), defined as the presence of any physical disruption of the structures of interest.

Results

After subperiosteal PPCDO in 20 fresh frozen cadaveric limbs, the sural nerve, medial plantar nerve, lateral plantar nerve, posterior tibial nerve, artery, and vein remained intact in all specimens. Inspection of each of the structures of interest, along their anatomic routes proximally and distally, revealed no evidence of iatrogenic neurovascular injury. Moreover, adequate medial translation had been accomplished in each of the specimens. The limiting factor in every specimen was the soft tissue envelope, including the periosteum, which was easier to displace if the envelope was thin (relatively thin specimen) and more difficult if the soft tissue envelope was thick

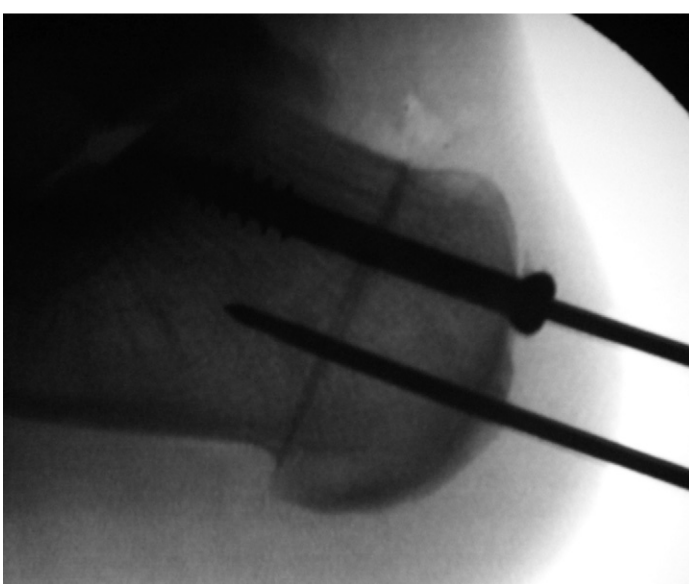

Fig. 5. Under fluoroscopy, wire placement checked using lateral and calcaneal views. After adequate wire placement, appropriate length screws were inserted.

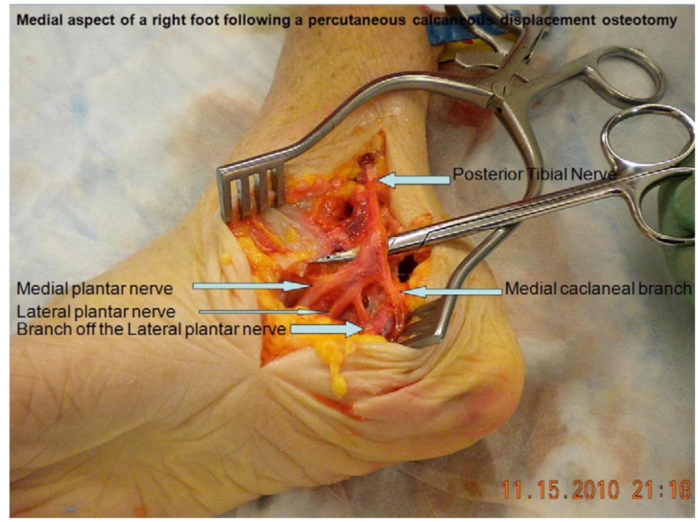

Fig. 6. Posterior tibial, medial, and lateral plantar nerves are superior and distal using medial approach, leaving only medial calcaneal branch and any anatomic variations in line of osteotomy.

(relatively heavier specimen, which was thought to correlate with a cadaver with a greater body mass index). We made clinical observations based on the cadavers and on live patients that enabled us to assume that those cadavers with thicker soft tissues were heavier. Furthermore, it became obvious that placement of the initial incisions posteriorly and medially allowed the surgeon to avoid most of the medial and lateral neurovascular structures when starting more posteriorly on the calcaneus. Furthermore, the posterior tibial, medial, and lateral plantar nerves all remained superior and distal to the medial incision used to approach the calcaneus, leaving only the medial calcaneal branch and any anatomic variations potentially in the line of the osteotomy and vulnerable to iatrogenic injury (Fig. 6). Finally, the sural nerve was also found to be localized anterior to the lateral osteotomy track in all cases (Fig. 7).

Discussion

Numerous anatomic structures, including the medial plantar, lateral plantar, medial calcaneal, sural, and posterior tibial nerves, as well as the associated arterial and venous structures, are susceptible

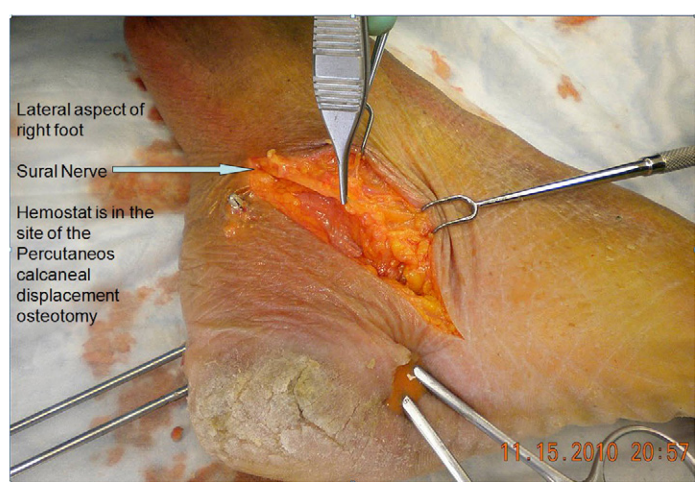

Fig. 7. Sural nerve shown anterior to lateral osteotomy site.

to trauma when performing PPCDO. Previous studies have also detailed the anomalous and variable neurovascular structures in this location (12–16). In 2001, Greene et al (6) evaluated 22 fresh frozen below the knee cadaver limbs after open PPCDO to determine the anatomic relationship of the medial neurovascular structures. That study showed that, on average, 4 anatomic structures and a minimum of 2 structures, crossed the osteotomy site. They also suggested that pain, numbness, and hematoma formation were particular postoperative complications experienced in association with PPCDO owing to iatrogenic injury of the vital structures, and they recommended that osteotomy of the medial calcaneus be performed in a restrained manner and with great care (6).

The anatomic variance of the neurologic structures of the medial calcaneus is extensive. Havel et al (12) dissected 68 cadaveric limbs and reported that the posterior tibial nerve bifurcated within the tarsal tunnel in 63 of the limbs (93%). In contrast, bifurcation occurred proximal to the tarsal tunnel in 5 limbs (7%). Furthermore, the calcaneal nerve demonstrated 9 variant patterns, with branching occurring within the tarsal tunnel in 34% and proximal to the tarsal tunnel in 35% of the limbs. A single branch was most common, occurring in 79% of the limbs. In a later study, Davis and Schon (13) reported that 90% of posterior tibial nerves bifurcated within 2 cm of an axis formed by the middle of the medial malleolus and calcaneus within the tarsal tunnel. Their results differed from those from Havel et al (12), in that multiple branches of the calcaneal nerve were more common with a 60% occurrence (13). Dellon et al (14) conducted a study of 85 tarsal tunnel releases and found that the calcaneal nerve had multiple branches in 63% of the cases.

In 2002, Casey et al (15) and, in 2009, Gamie et al (16), performed anatomic dissections on fresh frozen cadaver limbs to determine the “safe zone” for percutaneous pin placement on the medial aspect of the calcaneus using 3 and 4 anatomic sites. Both studies proposed that the more posterior the pin placement, the less risk of iatrogenically damaging the medial neurovascular structures. Additionally, Gamie et al (16) advocated caution because the medial neurovascular structures varied greatly in their study, particularly the medial calcaneal nerve. To avoid traumatizing vital structures, Casey et al (15) recommended the use of blunt dissection.

The goal of our study was to evaluate the anatomic structures adjacent to the body of the calcaneus after execution of a subperiosteal PPCDO using a gigli saw, with a focus on identifying any gross evidence of iatrogenic injury to the surrounding soft tissues. Although the aforementioned anatomic structures were inevitably in close proximity to the surgical site, none were observed to be damaged after completion of the osteotomy in the cadaver limbs we inspected. The percutaneous technique we have described in this report allowed direct blunt dissection down to the level of bone, avoiding the need for open surgical dissection. Importantly, using the design of our dissection, if care is not taken, rupture of the plantar fat and its tributary neurovascular structures could occur if the arms of the gigli saw are not gradually widened as the saw approaches the plantar cortex of the calcaneus. With a thorough knowledge of the anatomy, combined with optimal placement of minimal incisions, our surgical experience (not reviewed in this report), as well as the results of this investigation, leads us to believe that damage to adjacent vital anatomy can be avoided. We also believe that the percutaneous technique we have described could avoid common complications known to be associated with traditional open surgical dissection of the calcaneus, minimizing cutaneous scar formation and improving cosmesis, because only 4 stab incisions are used. Because PPCDO is usually undertaken in conjunction with multiple adjunct reconstructive procedures, we also believe that it minimizes stress on the soft tissue envelope that surrounds the calcaneus. This concept has also been previously noted (17). We also understand that the results of our cadaver study need to be evaluated in the clinical setting before we can truly understand the effects of PPCDO in patients. Thus, we believe that additional investigation is needed to compare the technique we have described with traditional open dissection methods for calcaneal osteotomy. In conclusion, our study has demonstrated that subperiosteal PPCDO is a predictable, apparently safe, and probably advantageous alternative to the open calcaneal osteotomy techniques.

References

1. Hansen ST. Surgical principles. In Functional Reconstruction of the Foot and Ankle, pp 80, 112, 370–372, edited by ST Hansen, Lippincott, Williams & Wilkins, Hagerstown, PA, 2000.
2. Myerson MS, Corrigan J, Thompson F, Schon LC. Tendon transfer combined with calcaneal osteotomy for treatment of posterior tibial tendon insufficiency: a radiographic investigation. Foot Ankle Int 16:712–718, 1995.
3. Frankel JP, Truf RM, Kuzmicki LM. Double calcaneal osteotomy in the treatment of posterior tibial tendon dysfunction. J Foot Ankle Surg 34:254–261, 1995.
4. Mendicino RW, Catanzariti AR, Reeves CI. Posterior calcaneal displacement osteotomy: a new percutaneous technique. J Foot Ankle Surg 43:332–335, 2004.
5. Cantanzaritia AR, Mendicino RW, King GI, Neerings B. Double calcaneal osteotomy realignment considerations in eight patients. J Am Podiatr Med Assoc 95:53–59, 2005.
6. Greene DL, Thompson MC, Gesink DS. Anatomic study of the medial neurovascular structures, in the relation to calcaneal osteotomy. Foot Ankle Int 22:569–570, 2001.
7. Weinfeld BS. Medial slide osteotomy technique, patient selection, and results. Foot Ankle Clin 6:89–94, 2001.
8. Mann RA, Guyton FP. Medial displacement osteotomy of the calcaneus and flexor digitorum longus transfer, in The Foot and Ankle, pp 369–85, edited by HB Kitaoka, Lippincott, Williams and Wilkins, Philadelphia, 2002.
9. Frankel J, Turf RM, Nichols D. Complications of calcaneal osteotomies. Clin Podiatr Med Surg 8:409–423, 1991.
10. Parks MD, Mirmiran R. Posterior calcaneal displacement osteotomy with lateral wall reduction. J Foot Ankle Surg 41:135–137, 2002.
11. Andermahr J, Helling H, Rehm KE, Koebke Z. The vascularization of the os calcaneum and the clinical consequences. Clin Orthop Relat Res 363:212–218, 1999.
12. Havel PE, Ebrahemi NA, Clark SE, Jackson WT, DiDio L. Tibial branching in the tarsal tunnel. Foot Ankle 9:117–119, 1988.
13. Davis TJ, Schon LC. Branches of the tibial nerve: anatomic variations. Foot Ankle Int 16:21–29, 1995.
14. Dellon AL, Kim J, Spaulding CM. Variations in the origin of the medial calcaneal nerve. J Am Podiatr Med Assoc 92:97–101, 2002.
15. Casey D, McConnell T, Parekh S, Tornetta P. Percutaneous pin placement in the medial calcaneus: is anywhere safe? J Ortho Trauma 18:39–42, 2002.
16. Gamie Z, Donnelly L, Tsiridis E. The "safe zone" in medial percutaneous calcaneal pin placement. Clin Anat 22:523–529, 2009.
17. Dull J, DiDomenico L. Percutaneous displacement calcaneal osteotomy. J Foot Ankle Surg 43:336–337, 2004.