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Minimally Invasive Calcaneal Osteotomy: Does the Shannon Burr Endanger the Neurovascular Structures? A Cadaveric Study

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ABSTRACT

Calcaneal osteotomies are used to correct hindfoot alignment. Traditional open procedures have been plagued with complications. Various minimally invasive techniques have been described but are laborious and time-consuming. A percutaneous technique using a side cutting "Shannon" burr offers a simple and reliable alternative; however, little evidence is available to address the safety concerns. The aim of the present study was to quantify the risk posed to the medial and lateral neurovascular structures using this technique. The study was performed at the anatomy department, University of Sussex, using 13 fresh-frozen, below-the-knee cadaveric specimens during a training session held by WG Healthcare UK, Ltd. (Letchworth, Herts). The participants were 11 consultant orthopedic surgeons, who were inexperienced in minimally invasive surgery, and 2 demonstrators. Each performed a chevron calcaneal osteotomy using a Shannon burr by way of a lateral percutaneous approach under fluoroscopic guidance. The authors subsequently dissected the specimens to identify the neurovascular structures, describe their anatomic relations and proximity to the burr, and note any damage incurred. No evidence was found of significant neurovascular injury. Two very small proximal branches of the sural nerve were transected, the nerve itself passing safely 9 to 21 mm anterosuperior to the entry point. The medial neurovascular bundle crossed the path of the osteotomy in 4 specimens but was protected by the medial head of the quadratus plantae muscle. In conclusion, the Shannon burr for calcaneal osteotomy has the potential to minimize the surgical morbidity and maximize surgical efficiency without compromising safety in all patients with normal anatomy of the quadratus plantae muscle.

A minimally invasive surgical procedure is any procedure less invasive than the traditional open surgery. Its aim is to achieve outcomes similar to those of an open procedure but through a smaller incision, thus minimizing soft tissue disruption and surgical morbidity. The past 2 decades have seen a considerable shift toward minimally invasive procedures, with arthroscopic procedures replacing open techniques in a number of surgical disciplines.

In foot and ankle surgery, a calcaneal osteotomy is used to treat a variety of pathologic entities in which the hindfoot alignment requires adjustment (1–3). Two popular approaches are the extended lateral incision (4) (or modifications thereof) and an oblique incision from the superior border of the calcaneus posterior to the calcaneal peroneal tubercle to the inferior extent of the proposed osteotomy (5). Extensile incisions in the hindfoot, however, have been plagued by wound healing problems, with Lamm et al (2) reporting an incidence of 5% wound complications requiring surgical debridement in 20 Dwyer osteotomies. A number of investigators have modified their

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Conflict of Interest: All data were taken from specimens provided by WG Medical for teaching staff and delegates during their minimally invasive surgery course. None of the study data were made available to employees of WG Medical until after their collection and analysis.

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surgical technique to address this issue. DiDomenico et al (6) described a percutaneous osteotomy using a Gigli saw inserted into a subperiosteal tunnel that looped up and over the calcaneus by way of 4 stab incisions. Their cadaveric study of 20 limbs revealed no neurovascular damage. Tennant et al (7) published the outcomes of a variant of this procedure in 25 patients in which they passed a suture through the subperiosteal tunnel under arthroscopic guidance before "shuttling" a Gigli saw along the track. None of the patients experienced a vascular injury; however, 1 had persistent numbness in the sural nerve distribution.

In the United Kingdom and France, a technique for percutaneous osteotomy has been developed by Walker and Redfern (8) and Vernois (9) using a modification of the Shannon burr (high-torque, low-speed, 3-mm Shannon burr; catalogue no. MI007; WG Healthcare UK, Ltd., Letchworth, Herts, UK) with end and side cutting performance. Currently, its use is restricted to consultants who have been specially trained. Although the benefits of this technique have already been recognized in forefoot reconstruction (10), its use in hindfoot surgery has been more cautious. In our unit, we have found the Shannon burr to be a safe, effective, and timesaving device for minimally invasive calcaneal osteotomy. A commonly voiced concern, however, that has not yet been addressed in the published data, is whether this technique puts neurovascular structures at risk.

Our study aimed to quantify the risk to the medial and lateral neurovascular structures when a Shannon burr was used for percutaneous chevron calcaneal osteotomy, using fresh-frozen cadaveric specimens in a "high-risk" situation in which most of the surgeons were novices to the technique.

Materials and Methods

The present study was performed at the anatomy department, University of Sussex (Brighton, UK). The cadaveric images used were taken with permission, under the auspices of the Human Tissue Authority license held by Brighton and Sussex Medical School. A total of 13 fresh-frozen below-the-knee cadaveric specimens were obtained for the present study. The study was performed during a training session conducted by WG Healthcare UK, Ltd. (Letchworth, Herts). The participants were 11 consultant orthopedic surgeons, who were inexperienced in minimally invasive (MI) surgery, and 2 experienced demonstrators. After a demonstration by an experienced MI surgeon, each surgeon performed an MI chevron calcaneal osteotomy, with guidance from the facilitators in a 2:1 ratio. Fluoroscopic guidance was available throughout the procedures.

Surgical Technique

The entry point was marked before the incision and was ascertained by obtaining a lateral radiograph of a Kirschner wire placed over the lateral aspect of the calcaneus in the desired position of the chevron osteotomy, taking care to avoid the subtalar joint, insertion of the plantar fascia, and Achilles tendon. A 1-cm longitudinal skin incision was made at the entry point, and artery forceps were used for blunt dissection to the calcaneus. A curved periosteal elevator was used for periosteal elevation on the superior and inferior aspects of the calcaneal body.

Using an artery forceps to protect the soft tissues, a 3-mm × 20-mm Shannon burr (WG Healthcare) was inserted into the entry point, ensuring that it was perpendicular to the skin. All threads of the burr were inserted into the bone through both cortices. Cuts were then made by way of the lateral entry point in the following order: dorsal cut lateral cortex, dorsal cut medial cortex, plantar cut lateral cortex, and plantar cut medial cortex. All cuts were performed using a lever action of the wrist, with the entry point acting as a fulcrum. Fluoroscopic guidance was essential to ensure the correct position of the cuts (Fig. 1).

Dissection

A minimum data set was collected from the participating surgeons: their previous MI surgical experience and their dominant hand. After the procedure, a lateral calcaneal radiograph was obtained to demonstrate the position of the osteotomy. The medial and lateral aspects of the heel were dissected by 2 authors (A.D., L.M.), who had not participated in the training, and examined the neurovascular structures for damage. Any anatomic variation was noted, including the presence or absence of a medial head of the quadratus plantae muscle and the position and number of the medial and lateral calcaneal nerve branches.

The same dissection steps for a lateral and medial approach were used for each specimen. A skin flap was raised on the deep fascia. On the lateral side, the short saphenous vein and its branches were identified, enabling localization of the sural nerve and its variable branches as they emerged 10 cm proximal to the insertion of the Achilles tendon on its lateral border (11). The course of the sural nerve was followed and its anatomy noted. For the purpose of radiographic measurement calibration, on the lateral side, the distance between the highest point of the calcaneal tuberosity and the highest point of the osteotomy was measured with calipers accurate to 0.1 mm, using burrs to mark each position. Second, 1 burr was inserted into the entry point. From this point, the minimal distance to the sural nerve and the closest lateral calcaneal branch were measured.

On the medial side, superficial dissection revealed a number of long saphenous vein tributaries, which were divided to enable access to deeper tissues. The medial flexor retinaculum was incised to allow dissection of the tendons of the tibialis posterior, flexor digitorum longus, and flexor hallucis longus, posterior tibial artery, medial plantar artery, lateral plantar artery, tibial nerve, medial plantar nerve, lateral plantar nerve, and medial calcaneal nerve. A burr was inserted through the entry point and another through the upper and lowermost points of the osteotomy. Unlike the lateral side, the medial structures were theoretically at risk throughout the whole length of the osteotomy owing to their exposure to the tip of the burr. Therefore, the minimum distance of any part of the osteotomy from the closest tibial nerve or artery and the closest medial calcaneal branch was measured. All data were analyzed using SPSS, version 20.0 (IBM Corp., Armonk, NY).

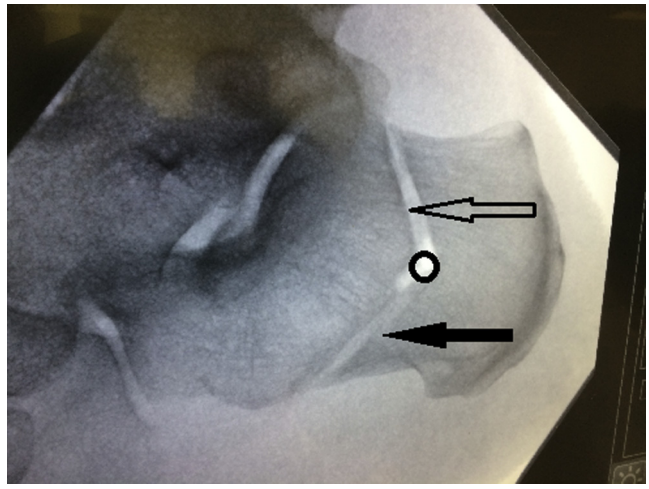

Fig. 1. Lateral calcaneal radiograph demonstrating the appropriate position of the osteotomy entry point *(black ring)* and the dorsal *(outline arrow)* and plantar *(block arrow)* cuts for a chevron osteotomy.

Results

Seven left and six right feet were dissected after completion of the calcaneal osteotomy. Thirteen different surgeons performed the osteotomies. Nine were performed using an MI burr for the first time and two for the second or third. The final 2 surgeons were demonstrators, pioneers of MI foot surgery in Europe, each with experience >200 procedures. All but 1 surgeon was right handed. The lateral entry point was consistently within a 20-mm × 8-mm ellipse in the center of the lateral wall of the calcaneal tuberosity. The position of the osteotomy on the medial side was less consistent and was spread over a large area of the calcaneal tuberosity (Fig. 2). In 4 cases, the proximally directed osteotomy was in direct line with the posterior tibial artery and/or tibial nerve if the burr had been advanced excessively through the osteotomy (Fig. 3).

Dissection of the lateral neurovascular structures demonstrated that the short saphenous vein was consistently superficial and anterior to the sural nerve. The number of lateral calcaneal nerve branches (branches of the sural nerve) varied from 1 to 5; the most common number was 2, occurring in 7 (53.9%) specimens. In 9 (69.2%) feet, a very small primary lateral calcaneal branch (i.e., the first branch from the sural nerve) was present that arose very proximally as the sural nerve left its posterior position and moved anteroinferiorly across the lateral aspect of the foot (Table). The minimum distance