The Journal of Foot & Ankle Surgery 53 (2014) 687–691

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Anatomic Structures at Risk: Curved Hindfoot Arthrodesis Nail—A Cadaveric Approach

Timothy Knight, MBBS [1], Peter Rosenfeld, MBBS, FRCS (Orth) [2], Ioan Tudur Jones, MB, BCh, FRCS (Orth) [3], Callum Clark, MB, BCh, FRCS (Orth) [4], Nick Savva, MBBS, FRCS (Orth) [5]

[1] *Specialist Registrar, West Midlands Deanery, Robert Jones and Agnes Hunt Orthopaedic Hospital, Gobowen, Oswestry, Shropshire, United Kingdom*
[2] *Orthopaedic Consultant Surgeon, St Mary's Hospital, London, United Kingdom*
[3] *Orthopaedic Consultant Surgeon, St Thomas' Hospital, London, United Kingdom*
[4] *Orthopaedic Consultant Surgeon, Heatherwood and Wexham Park Hospitals, Berkshire, United Kingdom*
[5] *Orthopaedic Consultant Surgeon, Dorset County Hospital, Dorset, United Kingdom*

ARTICLE INFO

Level of Clinical Evidence: 5

Keywords:
ankle
arthritis
cadaver
HAN
intramedullary nail
tibiotalocalcaneal fusion

ABSTRACT

Retrograde intramedullary nailing of the hindfoot and ankle is an established procedure for salvage of severe foot and ankle deformity, arthritis, tumor, and instability. In the present study, retrograde hindfoot (tibiotalocalcaneal) arthrodesis nailing was performed using a standardized technique on 7 cadaver specimens by trained senior surgeons. The specimens were then dissected to determine the distance of the subcalcaneal structures at risk from the insertion point of the nail. The findings showed that the distance of the lateral neurovascular bundle from the edge of the nail was 6.5 (range 3.5 to 8, 95% confidence interval 5.9 to 7.1) mm. No neurovascular bundle was compromised, and all were within a previously described "safe window."

Tibiotalocalcaneal arthrodesis is an established treatment option for arthritis of the ankle and subtalar joints. It has been used, but has not been limited to, as treatment of talar avascular necrosis, as salvage treatment in complex trauma, and in the presence of instability or severe deformity, such as from tumor resection (1). It has also been used in failed ankle joint replacement, failed union, and pseudoarthrosis (2–5). Intramedullary nailing has the benefit of not creating the bulky construct seen with plating and avoids the excessive soft tissue dissection associated with wound complications. The concept is not new; however, the fixation design and fixation entry point have been altered in an attempt to achieve maximal fixation and offer protection to the neurovascular structures. The most significant recent changes have been in the curvature of the nail design and claims of improved safety.

Moorjani et al (6) undertook a cadaveric study to ascertain the relative anatomic dangers of different theoretical nail entry points of arthrodesis nails with varying curvature designs to the respective neurovascular structures. In their cadaveric study, the distance from the center of the nail entry to the respective structures was measured. A distance of less than 10 mm was deemed unsafe when working with a reamer 9 mm in diameter. In all cases, the distance from the medial plantar nerve and artery was greater than 10 mm; however, they identified the lateral plantar nerve and artery as being at the greatest risk. In 1 case, the pin had passed through the lateral plantar artery; in another, the pin and lateral neurovascular bundle were touching; and in a third case, the pin had been inadvertently placed on the medial side of the lateral neurovascular structure, illustrating the potential for injury. The current, newer intramedullary nail designs now require validation and evidence to support their claims of protection of the neurovascular structures in light of the design changes.

The structural strength of the nail construct is achieved by driving a bony tunnel of maximal fixation through the calcaneum. The plantar surface of the calcaneum has a sagittal ridge traversing lateral to the mid-axis of the calcaneal body. A curved nail design, therefore, will accommodate an additional valgus nail angulation of 8°, requiring 12° of nail curvature to accommodate a relatively lateral plantar entry point, with a residual valgus alignment of 3° to 5° after insertion. A plantar-lateral entry point will be advantageous, because it is further from the course of the closest neurovascular bundle and the lateral plantar nerve and artery.

As used by the AO Foundation, the hindfoot (tibiotalocalcaneal) arthrodesis nailing (HAN), marketed by DuPuy Synthes (Johnson &

Financial Disclosure: None reported.
Conflict of Interest: None reported.

Address correspondence to: Timothy Knight, MBBS, Robert Jones and Agnes Hunt Orthopaedic Hospital, Gobowen, Oswestry, Shropshire SY7 10AG United Kingdom.
E-mail address: tknight@doctors.org.uk (T. Knight).

1067-2516/$ - see front matter © 2014 by the American College of Foot and Ankle Surgeons. All rights reserved.
http://dx.doi.org/10.1053/j.jfas.2014.06.005

Johnson, West Chester, PA) is a retrograde nail with multiple fixation methods (7). The entry of the nail is through the plantar lateral aspect of the body of the calcaneum.

Satisfactory retrograde nail results were described with a plantar approach almost 2 decades ago; however, the nail design has been refined in materials, instrumentation, and principles of biology. Previous work has defined a "window of safety" lateral to the midline (6) and supported the design of nails with curvature. The present study examined the anatomic location of the plantar lateral neurovascular bundle to the nail entry point to evaluate the purported benefits of protecting critical neurovascular structures (7).

Materials and Methods

Using a standard set of instrumentation, 7 experienced orthopedic surgeons familiar with the surgical technique followed a standardized procedure (7) to insert a guidewire for cannulated intramedullary HAN through the heel pad of unembalmed cadaveric lower limb specimens. We elected to examine nail placement of the curved HAN system in 7 below the knee cadavers provided for an industry-sponsored training exercise. Demographic information for the cadaveric specimens was not available; however, we did not believe this would affect the goal of our examination. Live image-intensifier roentgenographic views were available and were used. The equipment was prepared and assembled by trained company representatives.

Before performing the technique, the operating team was reminded of the standardized steps for the nail insertion. A fibula osteotomy was performed and, subsequently, the ankle and subtalar joint surfaces were prepared.

The entry point for the heel pad was achieved in a training-simulated "real theater" environment. Palpation of the heel pad and surface markings were used to estimate entry. The palpable bony ridge on the plantar lateral aspect of the calcaneum indicates the lateral column of the calcaneum.

In accordance with the operational technique guide, which includes illustrations, published by Synthes, "the entry point is in line with the tibial canal and the lateral column of the calcaneus, using a C-arm, identify the center of the tibial canal by placing a 3.2-mm guidewire along the canal. Draw a line (Fig. 1*A*). Palpate the centre of the lateral column of the calcaneus. Draw a line (Fig. 1*B*). The entry point is located at the intersection of these two lines, the incision should be in line with the longitudinal axis of the foot" (7).

The power-driven guidewire, targeted toward the center of the talus, was advanced. The position was confirmed using live image-intensifier imaging and direct vision. Once a satisfactory guidewire position had been achieved, the wire was advanced into the distal tibia, following the central axis of the tibia. In most cases, this was followed sequentially by measuring, reaming, and introduction of an intramedullary nail using standardized equipment. As a training session, some surgeons chose not to advance a nail; in these cases, the heel pad was later exposed (Fig. 2) and a reamer placed in situ (Fig. 3) for measurement. A 13-mm protection sleeve was used with the 13-mm cannulated reamer.

Subsequent to satisfactory completion of the procedure, the cadaveric feet were examined by the senior authors (N.S. and P.R.). The surgical wounds were extended, and the dissection was made extensile (Fig. 4). The lateral neurovascular bundle was identified between the first muscle layer (abductor hallucis, abductor digiti minimi, and flexor digitorum brevis) and the second muscle layer (flexor digitorum longus, flexor hallucis longus, flexor accessorius, and the lumbricals). Minimizing the damage to the adjacent structural attachments to the neurovascular bundle, it was carefully dissected and exposed. With assistance to hold and document the position, the distance relative

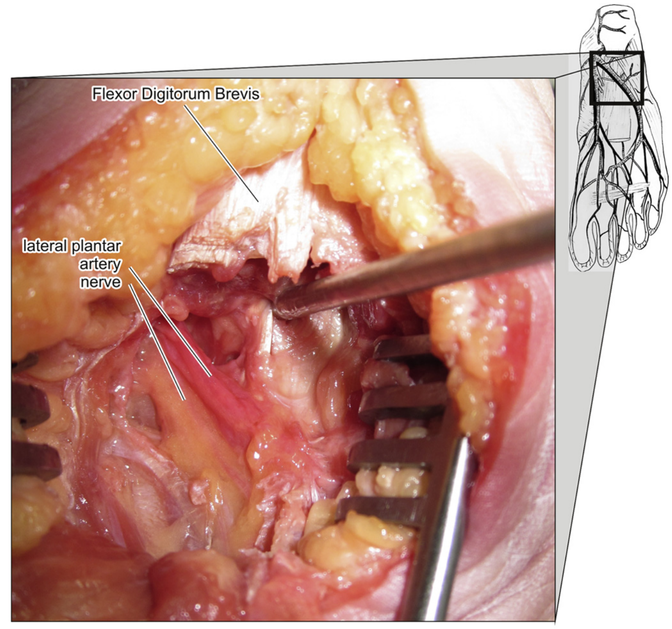

Fig. 2. Guidewire in situ demonstrating prereamed proximity to the neurovascular bundle.

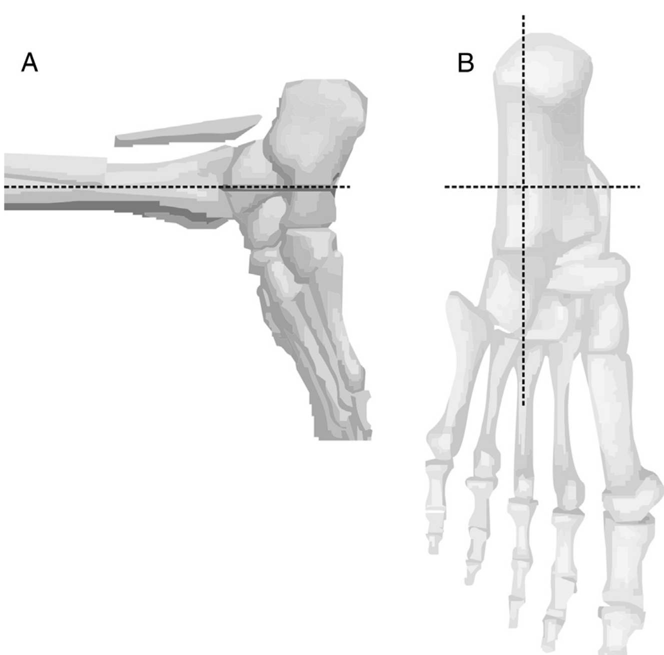

Fig. 1. Anatomic illustration of line markings along the axis of the tibia (*A*) and lateral column of the calcaneus (*B*). The entry point is located at the intersection of these 2 lines.

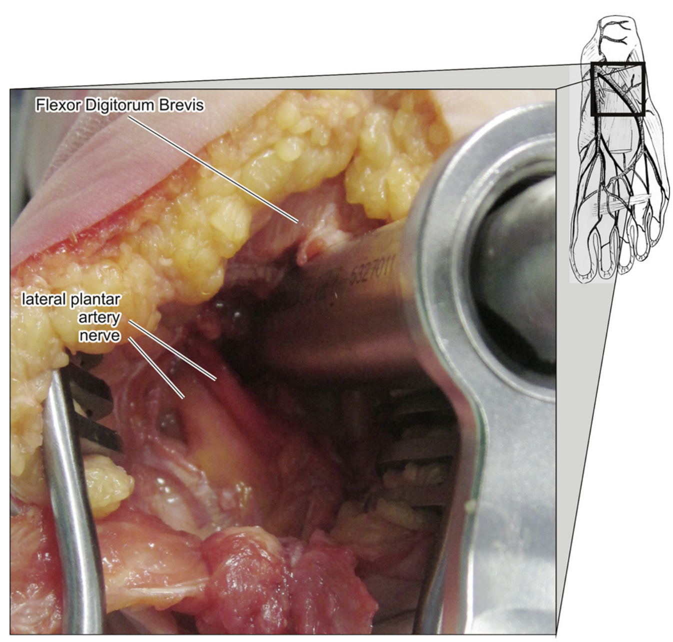

Fig. 3. Reamer and tissue protector positioned to demonstrate the close proximity of the neurovascular bundle.