Advantages of ultrasound identification of the distal insertion of the calcaneo-fibular ligament during ligament reconstructions.

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Research Article

Keywords: Ultrasonography, calcaneo-fibular ligament, ankle ligament reconstruction, ankle arthroscopy

Posted Date: April 19th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2828414/v1

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Abstract

Introduction: In lateral ankle instability, anatomical ligament reconstructions are generally performed using arthroscopy. The ligament graft is passed through the talus, fibular and calcaneal tunnels, reconstructing the anterior talofibular and calcaneofibular (CFL) bundles. However, the calcaneal insertion of the CFL needs to be performed in an extra-articular fashion, and cannot be carried out under arthroscopy, thus requiring specific anatomical landmarks. For obtaining these landmarks, methods based on radiography or surface anatomy have already been described but can only offer an approximate identification of the actual CFL anatomical insertion point. In contrast, an ultrasound technique allows direct visualization of the insertion point and of the sural nerve that may be injured during surgery. Our study aimed to assess the reliability and accuracy of ultrasound visualization when performing calcaneal insertion of the CFL with specific monitoring of the sural nerve.

Material and methods: Our anatomical study was carried out on 15 ankles available from a body donation program. Ultrasound identification of the sural nerve was obtained first with injection of dye. A needle was positioned at the level of the calcaneal insertion of the CFL. After dissection, in all the ankles, the dye was in contact with the sural nerve and the needle was located in the calcaneal insertion area of the CFL. The mean distance between the sural nerve and the needle was 4.8mm (range 3–7 mm).

Discussion-Conclusion: A pre- or intra-operative ultrasound technique is a simple and reliable means for obtaining anatomical landmarks when drilling the calcaneal tunnel for ligament reconstruction of the lateral plane of the ankle. This tunnel should preferably be drilled obliquely from the heel towards the subtalar joint (1h-3h direction on an ultrasound cross-section), which preserves a maximum distance from the sural nerve for safety purposes, while allowing an accurate anatomical positioning of the osseous tunnel.

Introduction

Three lateral ligament bundles can be found in the ankle: the anterior talofibular ligament (ATLF), the calcaneofibular ligament (CFL) and the posterior talofibular ligament. These ligaments maintain the stability of the ankle in flexion/extension and more particularly in inversion. They stabilize the tibiotaral joint through the anterior and posterior bundles, and the subtalar joint through the middle bundle [8]. Acute lateral ankle sprain injuries are the most frequent cause of consultations for ankle pathologies at emergency departments [5]. They can evolve towards lateral instability in 15 to 30% of cases, depending on intrinsic or extrinsic factors [12, 6, 14]. For treating these conditions of post-traumatic laxity, several surgical techniques allowing anatomical reconstruction are available [24, 3]. They consist in passing a ligament graft through several bone tunnels in the talus, the tip of the fibula and the calcaneus. Arthroscopic techniques are known to cause less morbidity, while improving accuracy when drilling the fibular and talar tunnel. They also allow to improve the diagnosis and the management of intra-articular lesions [4, 16]. However, the calcaneal insertion of the CFL can only be performed in an extra-articular fashion [8]: as arthroscopy is not available in this case, accurate anatomical landmarks are needed for successful insertion. Significant variations are observed on how to position the calcaneal tunnel among the many surgical reconstruction techniques described in the literature [17, 9, 15]. During this lateral ligament repair, the sural nerve is at risk of injury, due to its course close to the calcaneal area of the CFL reinsertion. The main purpose of this study was to assess the reliability of an ultrasound technique for guiding the calcaneal insertion of the CFL. A secondary objective was to assess the reliability of ultrasound for identifying the sural nerve and measuring its relationships with the calcaneal insertion of the CFL.

Materials And Methods

This study was carried out in the Laboratory of Anatomy of Rouen-Normandy University, on 15 ankles free of pathologies obtained from the body donation program (fresh embalmed bodies). The study involved an ultrasound technique followed by an anatomical analysis. The single operator (JB) was trained in foot and ankle ultrasound techniques. The first stage was ultrasound identification of the CFL (using Mylab Gamma from Esaote, equipped with a 5-15MHz linear probe), which crosses over the subtalar joint, then under the fibular tendons, finally reaching the lateral face of the calcaneus. Its visibility was increased when applying tension, by positioning the calcaneus in varus (Fig. 1a). The sural nerve was identified, in its lateral retro-malleolar part, as a satellite of the small saphenous vein. The nerve was identified in a proximal/distal fashion along the lateral face of the calcaneus. On a longitudinal cross-section of the CFL, the position of the nerve relative to the foot of the CFL was obtained using a watch dial method. As close as possible to the calcaneal insertion of the CFL, the sural nerve was identified by injecting a drop of dye under ultrasound control. A needle was then positioned, still under ultrasound control, at the level of the ligamentous insertion of the CFL, simulating the path of the guide pin of the calcaneal tunnel. This needle was positioned obliquely, from the heel towards the subtalar surface, making it possible to maximize the safety distance with the sural nerve on the surface, while being positioned at the level of the native in-depth insertion of the CFL.

A dissection of the entire lateral face of the calcaneus was then performed. The sural nerve and its curved course along the lateral aspect of the calcaneus were specifically sought in fatty tissues, then deeper into the fibular tendons and the distal insertion of the CFL. The nerve was
observed but not released for avoiding any modification of the following measured distances. Upon completion of dissection, several measurements were performed with an electronic caliper (Mitutuyo→)

- The smallest distance between the injected dye and the sural nerve,
- The smallest distance between the CFL ultrasound locating needle and its anatomical insertion point,
- The smallest distance between the needle and the sural nerve, as well as the respective positions of the sural nerve and CFL insertion point according to the watch dial method.

**Results**

On ultrasound, the sural nerve and the distal CFL insertion were easily identified in all cases. The CFL was best identified in a longitudinal cross-section with a probe oriented obliquely from the tip of the lateral malleolus, along the long axis of the calcaneus. This ligament was visible in the form of a hyper-echoic fibrillar structure, running under the fibular tendons. Identification of the sural nerve was obtained using a probe in a position transverse to the nerve path, in its lateral retro malleolar zone. A honeycomb structure (a follicular structure) which was a satellite of the short saphenous vein was sought. The nerve was then tracked, still in transverse cross-section, towards its curvature on the lateral face of the calcaneus (lift technique) (Fig. 1b) In a longitudinal cross-section of the CFL, by considering CFL insertion as the center of a clock, the sural nerve was always located between 10 and 12 o’clock (Table 1), thus allowing an oblique positioning of the clock’s hand in the opposite part of dial, between 1 and 3 o’clock. During the dissections, all anatomical structures were systematically identified. Concerning the identification of the sural nerve, the dye injected under ultrasound control was found in contact with the nerve in all cases (Fig. 2). The locating needle for CFL insertion was systematically found in the center of the anatomical bone insertion zone. The mean distance between the sural nerve and the needle was 4.8 mm (range 3–7 mm) (Table 1).

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Table 1 Distances measured (in mm) on the 15 ankles between the sural nerve and the needle implanted under ultrasound on the calcaneal insertion of the CFL.

the “watch dial” represents, on a longitudinal cross-section of the CFL, the position of the sural nerve in relation to the insertion point of the CFL.

**Discussion**

Our study confirmed the feasibility and reliability of an ultrasound technique for identifying the calcaneal insertion zone in the CFL. This technique also allows to preserve a safety margin to the sural nerve, thereby avoiding the main local anatomical risk involved in this type of procedure. We consistently obtained accurate anatomical landmarks on both the sural nerve and the CFL insertion area. This was predictable, as ultrasound mapping of these two structures has been described in multiple previous studies and as both structures are routinely explored [20, 10, 7]. Obtaining accurate anatomical identification of the CFL is essential for the reconstruction of the lateral ligament apparatus [18]. Many studies have covered the anatomical features of this ligament bundle. Its length and thickness are subject to little anatomical variation, unlike the LTFA [11]. Insertion in performed on the lateral surface of the calcaneus through a salient bony area (the tuberculum ligamenti calcaneofibularis) [25]. However, the latter appears as “well defined” in only 43% of cases, “atypical” in 64.5% and having a “variable morphology” in 35.5% of cases [18, 13]. Besides, the direction of the CFL from the fibula towards its insertion point may vary [25, 23]. Moreover, this method of identification may be affected by the positioning of the ankle. Thus, the bone insertion zone of the CFL appears difficult to determine clinically. This is why several authors have described techniques for obtaining landmarks:

- Many studies have used radiographic tracking with angular and millimetric measurements using bony points on an ankle placed in a standardized position [2]. However, these complex measurements using an irradiating technique are difficult to perform in daily clinical practice, and do not seem to take into account possible individual anatomical variability. Moreover, these studies have not been interested in neighboring anatomical elements. Only Michel et al. [19] carried out a study including secondary dissection and subsequent measurements in relation to the sural nerve and fibular tendons.
In an anatomical study of 30 cases conducted in 2016, Lopes et al. [17] proposed a purely cutaneous identification of the calcaneal insertion of the CFL, from the posterior face and the tip of the fibula. The advantage of this technique was its possible clinical applications, even though using standardized skin markers is not possible for all individual anatomies or in the case of modified bone and skin relief (due to obesity or sequelae from deformation).

Guillo et al. [9] described a technique for creating the calcaneal tunnel in an appropriate anatomical position by pushing lateral arthroscopic exploration in an extra-articular fashion under the fibular tendons to seek the native insertion of the CFL with the endoscope. This original anatomical technique made it possible not to perform a primary approach on the lateral face of the calcaneus but required a more invasive extra-articular detachment and did not allow to preserve the remaining ligamentous structures of the CFL.

Li et al. [15] compared the two positioning techniques (arthroscopic and percutaneous) mentioned above and found no difference in their respective outcomes, while pointing out that arthroscopic positioning resulted in anterior and inferior positioning in the center of the CFL, and that percutaneous positioning resulted in a posterior and inferior position.

Thus, all these techniques can only give access to approximate positioning of the calcaneal insertion of the CFL.

Reconstruction of the CFL by drilling a calcaneal tunnel requires a cutaneous approach on the lateral face of the calcaneus (with the exception of techniques positioning the tunnel arthroscopically [9]), thereby exposing the sural nerve, which is located very superficially within the subcutaneous fat, to possible damage. In the proximal part of this region, the sural nerve is a satellite of the lesser saphenous vein before curving when meeting the lateral face of the calcaneus, then following the course of the fibular tendons. It then divides more distally into two sensory branches innervating the lateral edge of the foot around the base of the 5th metatarsal [1, 21]. Two articles relative to the positioning of CFL focused on this nervous element: Michels et al. [19] found a distance of 1.4 mm +/-2 (0-5.8 mm) between the nerve and a pin positioned according to radiographic markers. Lopes et al. [17] found a distance of 1.1 mm +/-1.8 mm between a pin positioned using cutaneous distances and the nerve. In our study, the mean safety distance was markedly higher than in these two studies (4.8 mm, range 3–7 mm.), notwithstanding the drilling of a calcaneal tunnel with a diameter close to 5 mm. (i.e. 2.5 mm. around the guide pin).

Accurate visualization of the sural nerve is needed to prevent nerve damage during the lateral cutaneous approach towards the calcaneal tunnel. This cutaneous route (just like the bone tunnel) will preferably be carried out obliquely, from the distal part of the calcaneus towards the sinus of the tarsus, and from the surface inwards. It will thus become possible to reach the deep native insertion of the CFL, while remaining as far as possible from the superficial sural nerve within the subcutaneous fat (Fig. 3).

Using an ultrasound technique is a simple and reliable means for identifying the calcaneal insertion of the CFL, avoiding issues associated with variable bone or skin reliefs or standardized measurements that necessarily offer less anatomical accuracy. It also allows the reliable identification of the sural nerve, the anatomical element most at risk when carrying out a primary approach on the lateral face of the calcaneus. The identification is carried out using a longitudinal cross-section on the CFL. Relative to this insertion point and by using a watch dial method, the sural nerve is located between 10 and 12 o’clock, allowing the drilling of a calcaneal tunnel in a safety zone between 1 and 3 o’clock.

This study opens up the possibility of performing a calcaneal tunnel in an accurate anatomical position after ultrasound identification, which offers a simple, accessible, non-irradiating or invasive method. Identification can be done:

- Prior to the procedure: once the patient is installed on the operating table, the operator will locate the sural nerve on the skin surface. He/she will indicate by a skin mark the planned route of the calcaneal tunnel, as far as possible from the sural nerve. The surgical procedure is then carried out, with percutaneous creation of the CFL calcaneal tunnel according to the preoperative skin marking.
- During the procedure, by positioning the guide pin of the calcaneal tunnel under ultrasound guidance, with the probe draped under sterile conditions.

The size of our sample in this study was relatively similar to that observed in other studies. Best et al. [2] used radiographic identification on a sample of 10 ankles. Lopes et al. [17] used a sample of 30 ankles, while Li et al. [15] used 15 ankles.

A possible limitation of this study lies in the experience required for a competent handling of the ultrasound tool, which is not yet routinely used by surgeons. However, the CFL is easy to identify for any practitioner familiar with its anatomical features. Subcutaneous identification of the sural nerve is perhaps more difficult, notably when aided by proximal retro-malleolar identification (where its caliber is greater) then followed distally.

Another limitation may be related to variability in the branches of the sural nerve: even if the sural nerve divides into 2 terminal branches around the base of the fifth metatarsal bone (therefore distal to the CFL insertion zone), there are sometimes calcaneal branches of very small
caliber, stemming from the lateral retro-malleolar region and descending on the lateral face. These can be difficult to locate with ultrasound [22]. Lesions affecting these areas can lead to partial dysesthesia of the lateral face of the calcaneus.

Conclusion

Ultrasound-guiding is a simple and reliable technique for obtaining accurate anatomical landmarks during the calcaneal insertion of the CFL in surgical reconstructions. It allows the precise positioning of a calcaneal tunnel, while ensuring a safe distance from the sural nerve.

Declarations

Funding: no external funding is reported for this study by any author.

Conflicts of interest: BJ, RC, CC, ML report no conflict of interest for this study. F Duparc is co-editor in chief of the Journal Surgical and Radiologic Anatomy

Ethics approval: The study was conducted in compliance with the current rules and regulations for research activities of University of Rouen-Normandy

Consent to participate

All patients gave consent for the use of the ultrasound images in this study.

All donors were registered with the donated body program and their consent for anatomical studies had been obtained.

Consent for publication

All patients gave consent for the use of the ultrasound images for publication purposes.

All donors were registered with the donated body program and had provided consent for publication purposes.

Authors’ contributions

J. Beldame: Design of project, methodology, dissection, analysis of results, manuscript writing, editing.

C. Charpail : Design, methodology, dissection, analysis, writing, editing

M. Lalevée and R. Sacco: Dissection, writing

F. Duparc: Methodology, supervision, writing, editing

Disclosure: F Duparc is co-editor in chief of the Journal Surgical and Radiologic Anatomy

References


Figures
Figure 1

a: Photography of the ankle with US probe on a longitudinal cross-section of the CFL. Its visibility was increased when applying tension, by positioning the calcaneus in varus. The sural nerve was identified, in its lateral retro-malleolar part, as a satellite of the small saphenous vein.

b: Ultrasound cross-section of the lateral face of the calcaneus with longitudinal cross-section of the CFL. The short arrow represents the CFL underlying the 2 fibular tendons. The long arrow represents the sural nerve in cross section, adjacent to the lesser saphenous vein. The Star represents the most distal insertion of the CFL. The dial represents the direction of the needle positioning the calcaneal tunnel, oriented at 1 and 3 o'clock, while the sural nerve is located at around 11 o'clock.
Figure 2
Dissection of the lateral face of the calcaneus. The fibular tendons were sectioned and reclined. Performed under ultrasound and prior to dissection: injection of dye on the sural nerve (short arrow) and positioning of a needle at the level of the distal insertion of the CFL (including the part passing below the fibular tendons and marked with a long arrow).
Figure 3

Note the direction of the needle positioned under ultrasound control (obliquely from the heel towards the subtalar surface), representing the calcaneal tunnel in ligament reconstruction. This route allows to reach the deep native insertion of the CFL, while remaining as far as possible from the superficial sural nerve within the subcutaneous fat. Short arrow on the sural nerve; long arrow on the fibular insertion of the CFL, passing under the fibularis. The clock hand shows the direction of the calcaneal tunnel between 1 and 3 o'clock on the dial.