Original article

Cadaver study of anatomic landmark identification for placing ankle arthroscopy portals

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ABSTRACT

Background: Arthroscopy-assisted surgery is now widely used at the ankle for osteochondral lesions of the talus, anterior and posterior impingement syndromes, talocrural or subtalar fusion, foreign body removal, and ankle instability. Injuries to the vessels and nerves may occur during these procedures.
Objective: To determine whether ultrasound topographic identification of vulnerable structures decreased the risk of iatrogenic injuries to vessels, nerves, and tendons and influenced the distance separating vulnerable structures from the arthroscope introduced through four different portals.
Hypothesis: Ultrasonography to identify vulnerable structures before or during arthroscopic surgery on the ankle may be useful.
Material and method: Twenty fresh cadaver ankles from body donations to the anatomy institute in Strasbourg, France, were divided into two equal groups. Preoperative ultrasonography to mark the trajectories of vessels, nerves, and tendons was performed in one group but not in the other. The portals were created using a 4-mm trocar. Each portal was then dissected. The primary evaluation criterion was the presence or absence of injuries to vessels, nerves, and tendons. The secondary evaluation criterion was the distance between these structures and the arthroscope.
Results: No tendon injuries occurred with ultrasonography. Without ultrasonography, there were two full-thickness tendon lesions, one to the extensor hallucis longus and the other to the Achilles tendon. Furthermore, with the anterolateral, anteromedial, and posteromedial portals, the distance separating the vessels and nerves from the arthroscope was greater with than without ultrasonography (P = 0.041, P = 0.005, and P = 0.002, respectively; no significant difference was found with the anterior portal.
Discussion: Preoperative ultrasound topographic identification decreases the risk of iatrogenic injury to the vessels, nerves, and tendons during ankle arthroscopy and places these structures at a safer distance from the arthroscope. Our hypothesis was conﬁrmed.
Level of evidence: IV, cadaver study.

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1. Introduction

Arthroscopy is now widely used for surgical procedures on the ankle, including talocrural and subtalar fusion, foreign body removal, and treatments for osteochondral lesions of the talus (e.g., fractures, osteochondritis, and geodes), anterior and posterior ankle impingement syndromes, and ankle instability. Ankle distraction is used for some procedures.

Despite being minimally invasive and offering shorter recovery times compared to open surgery, arthroscopy carries several risks. Complications may develop, as reported by Small [1] in 1988.

Nerve injury is the most common complication, although frequencies have varied across studies (0% [1], 4% [2], 7% [3], 9% [4], and 14% [5]). The symptoms often resolve within 6 months. The superficial fibular nerve is the most often affected, followed by the saphenous nerve then by the saphenous nerve. Vascular injury may result in pseudoaneurysm formation on the anterior tibial artery [6,7], fibular artery [8], or dorsalis pedis artery [9]. Pseudoaneurysms at the ankle have also been reported after open tibial fracture surgery [10]. Nerve injuries, most notably to the superficial fibular nerve, are common and difficult to prevent due to the many interindividual differences in anatomic features (trajectory, branching level, number of branches, and position changes during ankle flexion) [11–13]. Suzangar and Rosenfeld conducted a retrospective study of patients treated between 2005 and 2009 [14]. The superficial peroneal nerve and its branches were routinely marked before surgery, after being identified by visual inspection and palpation.
with the foot inplantar flexion and inversion. Of the 96 patients, only 1 had a surgery-related nerve injury, which manifested as sensory loss over the dorsum of the foot, with persistence of this symptom after 12 months.

Ultrasoundography before or during surgery may deserve consideration as a means of decreasing the risk of iatrogenic injuries to nerves, vessels, and tendons during arthroscopic procedures on the ankle, by ensuring that the portals are placed at a distance from these structures.

We conducted a cadaver study to test the hypothesis that preoperative or intraoperative ultrasoundography to identify vulnerable structures decreased the risk of iatrogenic injury during arthroscopy portal placement. The primary evaluation criterion was the ability to accurately locate the vulnerable structures at the ankle using ultrasoundography. The secondary evaluation criterion was estimation of the safety margins during arthroscopic portal placement.

2. Material and method

2.1. Cadaver specimens

In April 2015, we studied 20 fresh cadaver ankles from body donations to the medical school pathology institute in Strasbourg, France. Ankles with a history of surgery, scars, or deformities were excluded.

Ultrasound topographic identification of vulnerable structures, portal placement, and portal dissections were performed by a single orthopaedics surgery resident previously trained in ankle arthroscopy (BS).

The 20 ankles were divided at random into two groups of 10 ankles each. In one group, ultrasoundography was performed preoperatively to identify the great saphenous vein, anterior tibial neurovascular bundle, superficial fibular nerve, posterior tibial neurovascular bundle, and neighbouring tendons. Each of these structures was marked using a skin marking pen. An 18-MHz probe (Esoate Medical, Saint-Germain-en-Laye, France) was used for ultrasoundography (Appendices 1–4).

2.2. The portal placement methods

2.2.1. After ultrasound topographic identification

A 4-mm trocar was used to create three anterior and two posterior portals. All three anterior portals were created with the ankle in dorsal flexion (which was possible for all ankles) to minimise the risk of iatrogenic lesions [15]. The anteromedial portal was placed between the tibialis anterior tendon laterally and the medial malleolus medially. The anterolateral portal was immediately medial to the medial border of the lateral malleolus and lateral to the fibularis tertius tendon. The anterior portal was between the extensor hallucis longus tendon and extensor digitorum longus tendon. The two posterior portals were created using the method described by van Dijk and van Bergen [4], which is the most reproducible and safest technique [16]. The posterolateral portal was created first, using forceps inserted parallel to the sole of the foot and directed towards the first inter-metatarsal space down to bone contact. The posteromedial portal was then created medial to the Achilles tendon and lateral to the tibialis posterior, flexor hallucis longus, and flexor digitorum tendons. A trocar was introduced perpendicular to the forceps inserted through the posterolateral portal, to bone contact, then advanced into the joint.

2.2.2. Without ultrasound topographic identification

In the other group of 10 ankles, ultrasonography was not performed. The five above-described portals were created after clinical identification of vulnerable structures, based on operator experience. The posteromedial portal was created as described by van Dijk and van Bergen [4], i.e., after creation of the posterolateral portal.

2.3. Dissections

For all ankles, a 4-mm trocar was left in place in the posterolateral portal. The other four portals (anterior, anterolateral, anteromedial, and posteromedial) portals were dissected (Figs. 1–4).

2.4. Measurement methods

Any injuries to nerves and/or vessels were identified. The distance between the arthroscope and the nerves and vessels at
risk was measured for each portal. The structures at risk were as follows: anterolateral portal, superficial fibular nerve; anterior portal, anterior tibial neurovascular bundle; anteromedial portal, greater saphenous vein; and posteromedial portal, posterior tibial neurovascular bundle. For each portal, the mean distance was computed in each group. The groups were then compared by applying the non-parametric Mann-Whitney test, which was suited to the small sample size. Values were negative if the arthroscope was lateral to the structures at risk and positive otherwise.

3. Results

The posterolateral portal was not studied, as the study focussed on the anterior and posterior tibial bundles, superficial fibular nerve, and greater saphenous vein. This portal was created to allow the subsequent creation of the posteromedial portal in the groups with and without ultrasonography. Furthermore, the lateral sinus tarsi portal was not investigated.

3.1. Group with ultrasonography (Table 1)

No injuries to nerves, vessels, or tendons occurred in this group. In 1 ankle, the trocar was in contact with the superficial fibular nerve during use of the anterolateral portal. The mean distances between the arthroscope and the structure at risk were as follows:

- anterolateral portal, superficial fibular nerve, 3.5 mm (range: −6 mm to +7 mm);
- anterior portal, anterior tibial bundle, 6.1 mm (range: 0 mm to +15 mm);
- anteromedial portal, greater saphenous vein, 6.8 mm (range: −12 mm to +6 mm);
- posteromedial portal, posterior tibial bundle, 9.4 mm (range: −13 mm to +9 mm).

3.2. Group without ultrasonography (Table 2)

There were no injuries to nerves or vessels. In 1 ankle, insertion of the arthroscope through the anterior portal caused a full-thickness injury to the extensor hallucis longus tendon. In another ankle, the arthroscope inserted through the posteromedial portal caused a full-thickness injury to the Achilles tendon. The mean distances between the arthroscope and the structure at risk were as follows:

<table>
<thead>
<tr>
<th>Ankle #</th>
<th>AL/SFN (mm)</th>
<th>A/ATB (mm)</th>
<th>AM/GSV (mm)</th>
<th>PM/PTB (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0</td>
<td>−10</td>
<td>−13</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>10</td>
<td>−8</td>
<td>−13</td>
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<td>4</td>
<td>−6</td>
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<td>5</td>
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<tr>
<td>10</td>
<td>−5</td>
<td>5</td>
<td>−5</td>
<td>−10</td>
</tr>
<tr>
<td>Mean</td>
<td>3.5</td>
<td>6.1</td>
<td>6.8</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Table 1 Distances between the arthroscope and vulnerable structures in the group of 10 ankles with preoperative ultrasound topographic identification.

Table 2 Distances between the arthroscope and vulnerable structures in the group of 10 ankles without preoperative ultrasound topographic identification.

AL: anterolateral portal; SFN: superficial fibular nerve; A: anterior portal; ATB: anterior tibial bundle; AM: anteromedial portal; GSV: greater saphenous vein; PM: posteromedial portal; PTB: posterior tibial bundle.
Table 3
Comparison of the groups with and without ultrasonography regarding mean distance between the arthroscope and structure at risk.

<table>
<thead>
<tr>
<th>Mean distance (mm)</th>
<th>With US</th>
<th>Without US</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL/SFN</td>
<td>3.5</td>
<td>1.8</td>
<td>0.041</td>
</tr>
<tr>
<td>A/ATB</td>
<td>6.1</td>
<td>3.7</td>
<td>0.086</td>
</tr>
<tr>
<td>AM/CSV</td>
<td>6.8</td>
<td>4.5</td>
<td>0.005</td>
</tr>
<tr>
<td>PM/PTB</td>
<td>9.4</td>
<td>4.5</td>
<td>0.002</td>
</tr>
</tbody>
</table>

AL: anterolateral portal; SFN: superficial fibular nerve; A: anterior portal; ATB: anterior tibial bundle; AM: anteromedial portal; GSV: greater saphenous vein; PM: posterior medial portal; PTB: posterior tibial bundle.

- anteromedial portal, superficial fibular nerve, 1.8 mm (range: −4 mm to +3 mm);
- anterior portal, anterior tibial bundle, 3.7 mm (range: 0 mm to +13 mm);
- anteromedial portal, greater saphenous vein, 4.5 mm (range: −12 mm to +5 mm);
- posterior medial portal, posterior tibial bundle, 4.5 mm (range: −6 mm to +8 mm).

In this group, when all portals were pooled, the structure most often at risk was the superficial fibular nerve, which was in contact with the arthroscope in 30% of cases. The anterior tibial bundle was the next structure at greatest risk.

The superficial fibular nerve was the structure most at risk in both groups and for all portals pooled. The mean distance from the arthroscope was 1.8 mm without ultrasonography and 3.5 mm with ultrasonography. The difference is statistically significant ($P = 0.04$) (Table 3).

4. Discussion

No injuries to tendons occurred with any of the four portals when ultrasonography was used for preoperative topographic identification. In contrast, without ultrasonography, there were two full-thickness tendon injuries, one to the extensor hallucis longus with the anterior portal and the other to the Achilles tendon with the posteromedial portal.

Our hypothesis and study objective were confirmed. Preoperative ultrasonography for topographic identification benefits the optimal placement of ankle arthroscopy portals, most notably the anteromedial, anterolateral, and posteromedial portals. This method is also useful for creating the anterior portal: thus, in our study, the extensor hallucis longus tendon was injured in 1 case without ultrasonography versus no cases with ultrasonography. A limitation to preoperative or intraoperative ultrasonoid identification is that the operator must work through a learning curve. Depending on the echogenicity of the ankle, ultrasound identification of the nerves, vessels, and tendons at risk may take several minutes.

Although our study demonstrates that ultrasound topographic identification is useful, our sample size was small, with only 10 ankles in each group. A similar study in a larger sample would provide greater statistical power, which might translate into stronger evidence that ultrasonography is beneficial. In addition, we did not study the posterolateral and lateral sinus tarsi portals, which are used for ankle arthroscopy. More specifically, a study of the distance between the arthroscope and sural nerve with these portals would be of interest. In our study, the ultrasonography, portal placement, and dissection were all performed by a single operator, who was an orthopaedics surgery resident previously trained in ankle arthroscopy. Full-thickness injury to the Achilles tendon during use of the posteromedial portal, as occurred in 1 ankle, is not a classic complication. Performing a similar study with a more experienced operator therefore seems in order. The operator in our study had no previous training in ultrasonography. Thus, ultrasound topographic identification does not require a trained radiologist.

The superficial fibular nerve was the structure most at risk both with and without ultrasound topographic identification and for all portals pooled. The mean distance from the arthroscope was 1.8 mm with ultrasonography and 3.5 mm without ultrasonography (statistically significant difference, $P = 0.041$) (Table 3), in keeping with previous data reported by Oliva et al. [17]. The reason for this finding is probably the considerable anatomic variability regarding the trajectory, number of branches, and branching level of the superficial fibular nerve, as demonstrated by Lemont [11,12] and Wahee et al. [18]. The significantly shorter distance separating the arthroscope from the superficial fibular nerve without preoperative ultrasound topographic identification supports the usefulness of this procedure as a preliminary to anterolateral portal placement. Furthermore, clinical identification of the superficial fibular nerve with the foot in planter flexion and inversion is not always feasible. In contrast, ultrasonography consistently identified this nerve in our study.

Ultrasound topographic identification was not associated with a statistically significant difference in the distance separating the arthroscope in the anterior portal from the anterior tibial bundle ($P = 0.086$) (Table 3). Nevertheless, there are numerous reports of tibial artery pseudoaneurysms related to the creation of the anterior portal, including those by Darwich et al. [6] and Brimmo and Parekh [7]. Accurate ultrasound identification of the bundle can probably prevent this complication. In a cadaver study, Buckingham et al. [19] described a medial midline portal between the tibialis anterior tendon medially and extensor hallucis longus tendon laterally. They felt that this portal considerably diminished the risk of nerve and vessel injuries while allowing good exposure, compared to the central anterior portal.

The distance between the arthroscope in the anteromedial portal and the greater saphenous vein was significantly greater with ultrasonography ($P = 0.005$) (Table 3). Similarly, with the posteromedial portal, the distance separating the arthroscope from the posterior tibial bundle was significantly greater with ultrasonography ($P = 0.002$) (Table 3). An accessory posteromedial portal described by Roussignol et al. [20] in 12 cadavers to allow posterior tendinoscopy was not associated with any instances of nerve or vessel injury.

These data suggest a need for considering routine preoperative ultrasound topographic identification of nerves and vessels with or without concomitant identification of tendons. This imaging procedure can be performed by the surgeon, although previous training is required. A more reasonable strategy may consist in reserving ultrasound topographic identification for patients with limited range of motion at the ankle or a history of surgery (scars), two factors that can substantially change local topography.

Disclosure of interest

Professor Philippe Clavert is a consultant for Tornier and Mitek.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.otsr.2016.09.026.
References