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A novel method to correctly place the fasciotomy incision for decompression of the anterior and peroneal compartments of the leg

Ian Pallister [a,*], Rhys M. Morris [b], Tom Lloyd [c], Nicholas J. Marsden [d], Thomas Wright [e], Michael Gilbert [f], Jonathan Phillips [g]

[a] Department of Trauma & Orthopaedics, Morriston Hospital, College of Medicine, Swansea SA6 6NL, United Kingdom
[b] Department of Trauma, Morriston Hospital, College of Medicine, Swansea SA6 6NL, United Kingdom
[c] F1 Doctor, Wales, United Kingdom
[d] Plastic Surgery SpR, Welsh Centre for Burns & Plastic Surgery, Morriston Hospital, Swansea, United Kingdom
[e] Frenchay Hospital, Bristol, United Kingdom
[f] Morriston Hospital, United Kingdom
[g] Institute of Life Science, College of Medicine, Swansea University SA2 8PP, United Kingdom

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ABSTRACT

Incorrectly placed fasciotomy incisions can lead to catastrophic complications in compartment syndrome. Two distinctly different techniques are widely practiced to decompress the anterior and peroneal compartments. In one technique the anterior compartment is decompressed directly, and then the peroneal via the inter-muscular septum, avoiding the peroneal perforators. The second technique relies on surface anatomy landmarks to place the skin incision immediately over the inter-muscular septum, and then the respective fascial envelopes are incised separately.

A study in healthy active volunteers was conducted to explore the feasibility of a new technique for the placing the incision very accurately over the inter-muscular septum and so avoiding perforator vessels. Hypothesis The inter-muscular septum can be reliably identified using hand-held ultrasound, and confirmed with MRI.

Methods: Fourteen healthy active volunteers underwent hand-held ultrasound to identify the antero-lateral inter-muscular septum in the left lower limb, which was then marked using cod liver oil capsules. The positions of the anterior, septal and peroneal perforators were then identified using hand-held Doppler, and marked in the same way. MRI was then used to measure the relationship between the surface land marks, the septum (compared to its US position), and the relationship of the perforators themselves.

Results: Hand held ultrasound was successful in identifying the position of the inter-muscular septum in healthy volunteers, as confirmed on MRI scanning. The position and number of peroneal and anterior perforators proved very variable. Direct decompression of the anterior compartment would result in the loss of all anterior perforators in all subjects. Decompression with the skin incision over the inter-muscular septum would not jeopardise any peroneal muscular perforators.

Conclusion: This new technique enables decompression both the anterior and peroneal compartments through an accurately placed incision, sparing the greatest number of perforators. Two brief case histories in which the technique was used are presented.

Background

Failure to adequately decompress all four compartments in the lower limb has disastrous consequences, which at best may result in the loss of a limb, and at worst, may prove fatal [1,2].

Two techniques have been described for the decompression of the anterior and peroneal compartments. In one, the surgeon attempts to place the skin incision directly over the inter-muscular septum between the anterior and peroneal compartments [3]. Each is then decompressed by a separate deep incision releasing the fascia directly over each compartment. In a very swollen or malaligned limb, it is possible to misplace the skin incision, and so have difficulty locating the inter-muscular septum. Undermining the skin edges may prove necessary and if the surgeon has not

* Corresponding author. Tel.: +44 01792703166.
E-mail address: ianpallister@hotmail.com (I. Pallister).

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orientated themselves correctly it is possible to fail to decompress the anterior compartment. Furthermore, if placed too lateral, it has been suggested that the incision will compromise the peroneal perforators which may provide a useful soft tissue reconstruction option in the case of certain patterns of open fracture. If damaged, a patient may be consigned to having a free tissue transfer in an injury which was otherwise amenable to a local flap.

The alternative approach places the skin incision much more anteriorly and decompresses the anterior compartment directly by incising the fascia exactly in line with the skin incision, about 1.5–2 cm lateral to the tibial crest [4,5]. This is then followed by medial retraction of the muscle bulk of the anterior compartment to allow decompression of the peroneal compartment by incision of the inter-muscular septum. Direct decompression the anterior compartment is assured and undermining the skin to locate the inter-muscular septum is unnecessary, and the peroneal muscular perforators will not be compromised. However, there are risks including damage to the superficial branch of the common peroneal nerve when incising the inter-muscular septum [6], poor vascularity and blistering of the narrow skin bridge over the tibial fracture itself. Finally, if a below knee amputation is ultimately required, then fashioning of the flaps to close the amputation is very challenging.

Fasciocutaneous flaps are a mainstay in soft tissue reconstruction following open fractures in the lower limb, thanks to better understanding of the consistent nature of perforating vessels and the three dimensional territories supplied by them [7–10]. These territories (angiosomes) are blocks of tissues supplied by perforators which arise from the deep principal vessels of the limb, traverse compartments, pierce the deep fascia and then arborise to supply the subcutaneous tissue and skin. Perforators may be muscular or septal, depending upon whether they penetrate the substance of a muscle belly en route to the deep fascia, or run a course intimately related to an inter-muscular septum. The anatomical relationships were described in detail using cadaveric material and injection techniques, followed by exhaustive dissection [9,10]. Experience indicates that these findings have translated well into clinical practice. Due to the importance of preservation of perforating blood vessels and adequacy of surgical decompression in compartment syndrome, a new technique is proposed for anterior and peroneal compartment fasciotomy.

In the emergency clinical setting, simple hand-held ultrasound devices are regularly used for the safe provision of nerve blocks for pain relief. Similarly, hand-held Doppler devices are also used to check both peripheral circulation and the location of perforator vessels in severe lower limb trauma.

By using these techniques in the clinical setting it should prove possible to safely identify, mark and incise the skin directly over the anterolateral inter-muscular septum, while avoiding compromising perforators and unnecessary skin edge undermining.

Hypothesis (:).
The inter-muscular septum can be reliably identified using hand-held ultrasound, and confirmed with MRI.

Method

A non-invasive study normal active volunteers was conducted. Medical students were approached after agreement from the College of Medicine, Swansea, and confirmation from the South West Wales Research Ethics Committee that formal ethical approval was not required. Exclusion criteria were all the conventional contra-indications for MRI, plus previous compartment syndrome, previous surgery to the left lower limb below the knee, and any congenital anomalies of the lower limb (e.g. talipes, fibula hemimelia, etc.). Prior to undergoing imaging, volunteers were required to read the standard Swansea University Volunteer MRI Information Sheet and complete the MRI Procedure Volunteer Safety Questionnaire. The study was conducted in the Clinical Imaging Facility in the Institute of Life Sciences 2 Building, Singleton Campus, Swansea University.

All examinations were made on the volunteers' left lower limbs. Using an indelible pen, the lateral maleolus, fibular head and the tibial crest were marked, the line of the fibula indicated, and the position of the BOA/BAPRAS recommended direct anterior fasciotomy drawn, 1.5–2 cm lateral to the tibial crest.

Doppler ultrasound was used to identify the relevant perforator blood vessels. Subjects lay supine on an examination couch with their leg in a neutral position. Perforators were identified using a Huntleigh Mini Dopplex D900 (Huntleigh Health Care Ltd, Cardiff, UK) handheld doppler, with a 8Mhz probe and a peak sensitivity at 20 mm tissue penetration. First the dorsalis pedis artery was located in the foot and tracked proximally into the leg. At points where the signal became significantly louder a mark was placed to indicate a perforator from the anterior tibial artery. Next, the probe was positioned just posterior to the line of the subcutaneous border of the fibula proximal to the lateral malleolus. A "lawnmower" type action was used to detect and mark the most distal perforator. This mark was then used to identify more proximal perforators in the same coronal plane in a similar fashion. The perpendicular distance of each perforator from the marked fasciotomy line was then measured and recorded. These perforators were marked using MRI visible markers (cod liver oil capsules). Anterior perforators have a simple intra-muscular path. Perforators running in the inter-muscular septum between the anterior and peroneal compartments were identified as septo-crural perforators. Those which traversed the peroneal muscle bellies were muscular perforators. More posteriorly still, posterior septal perforators were identified in the inter-muscular septum between the peroneii and the posterior compartment. These relationships were recorded.

Ultrasound of the anterior compartment was performed by a trained ultrasound operator, whose practice consists mostly of cardiac and vascular ultrasound. The operator reviewed local and published training material for lower limb ultrasound lower limb prior to commencement of the study [11]. A Sonosite® S-Nerve point-of-care portable ultrasound scanner with an HFL38 × 6–13 MHz linear transducer (FUJIFILM-Sonosite Ltd., London EC4A 3TW, United Kingdom), was used to scan the anterior and lateral aspects of the lower leg. Acoustic shadowing caused by the tibia was used as the marker of the medial borders of the anterior compartment (Fig. 1a). Starting proximally, just below the tibial tubercle, the ultrasound transducer was moved laterally towards the fibula, to acquire an axial cross-sectional view of the antero-lateral aspect of the proximal lower leg, and to identify the muscles of the anterior compartment and the inter-muscular septum between anterior and peroneal compartments. The inter-muscular septum was followed distally, keeping the junction of the septum and the deep fascia in the centre on the scanning image, until the septum disappeared just above the level of the lateral malleolus. Marks on the skin, aligned with the centre of the ultrasound transducer, were made with indelible marker pen at 4–5 cm intervals.

The volunteers limbs were then photographed from an antero-lateral view, to include the markings of the lateral maleolus and fibular head, with the fasciotomy incision line just visible (Fig. 2). These images were used to compile a composite picture of the distribution of the alignment of the inter-muscular septum and perforators for all of the volunteers (Fig. 3). The distances of each