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Identifying the Emergence of the Superficial Peroneal Nerve through the Deep Fascia on Ultrasound and by Dissection: Implications for Regional Anesthesia in Foot and Ankle Surgery

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Abstract

Regional anesthesia relies on a sound understanding of anatomy and the utility of ultrasound in identifying relevant structures. We assessed the ability to identify the point at which the superficial peroneal nerve (SPN) emerges through the deep fascia by ultrasound on 26 volunteers (mean age 27.85 years ±13.186; equal male:female). This point was identified, characterized in relation to surrounding bony landmarks (lateral malleolus and head of the fibula), and compared to data from 16 formalin-fixed human cadavers (mean age 82.88 years ±6.964; equal male:female). The SPN was identified bilaterally in all subjects. On ultrasound it was found to pierce the deep fascia of the leg at a point 0.31 (±0.066) of the way along a straight line from the lateral malleolus to the head of the fibula (LM-HF line). This occurred on or anterior to the line in all cases. Dissection of cadavers found this point to be 0.30 (±0.062) along the LM-HF line, with no statistically significant difference between the two groups (U=764.000; exact 2-tailed p=0.534). It was always on or anterior to the LM-HF line, anterior by 0.74 cm (±0.624) on ultrasound and by 1.51 cm (±0.509) during dissection. This point was significantly further anterior to the LM-HF line in cadavers (U=257.700, exact 2-tailed p<0.001). Dissection revealed the nerve to divide prior to emergence in 46.88% (n=15) limbs, which was not identified on ultrasound (although not specifically assessed). Such information can guide clinicians when patient factors (e.g. obesity, peripheral edema) make ultrasound-guided nerve localization more technically challenging.

Key words

Block; nerve anatomy; regional anesthesia; superficial peroneal nerve; ultrasound

Introduction

Knowledge of sensory innervation throughout the body allows anesthetists to target specific nerves with local anesthetic in order to block the nociceptive sensory stimuli being relayed to the brain, where it is perceived as pain. An ankle block targets the tibial, deep and superficial peroneal (fibular), saphenous and sural nerves. It can be used as the sole anesthetic technique for foot and ankle surgery, or in combination with general/spinal anesthesia to provide excellent post-operative analgesia (Purushothaman et al., 2013).

Descriptions of these nerves typically follow that of well-established anatomical texts, such as Standring (2008), Sinnatamby (2011) and Moore et al. (2014). However, these often do not catalogue the full extent of natural anatomical variation, particularly in relation to regional anesthesia, which is also true of relevant clinical material such as Purushothaman et al. (2013) and McLeod et al. (2013). Structural and functional dissimilitude is of importance to regional anesthetists targeting specific nerves, as incomplete anatomical knowledge can mean one is unable to identify (or incorrectly identifies) the relevant nerve. Alternatively, the correct nerve is targeted but a suboptimal outcome is achieved as demonstrated by Keplinger et al. (2018), who suggest that clinical assessment of sensory innervation shows a high degree of variability.

Chin et al. (2001) showed a 16% failure rate for ultrasound-guided ankle block (higher for anatomic landmark-based techniques), which could be in part explained by missing relevant nerves due to anatomical variation. Our personal clinical experience is that the dorsum of the foot, in the region supplied by the superficial peroneal nerve (SPN), may develop incomplete anesthesia, requiring supplemental infiltration of local anesthetic, intravenous opioid or unplanned conversion to general anesthetic.

The authors believe that variation in the SPN site targeted during an ankle block, the point at which it pierces the deep fascia, may contribute to an incomplete or failed block. Furthermore, compared to the other four nerves targeted during ankle block, the SPN does not have a reliable vascular landmark to assist the anesthetist in localizing the nerve. Therefore, characterizing this variation is of use to anesthetists performing an ankle block and other clinicians operating in this area (e.g. orthopedic surgeons operating on the distal fibula). Pacha et al. (2003) assessed this position as a percentage of fibula length on preserved cadaveric material. They determined the mean distance to be 33.5% of the distance from the lateral malleolus (LM) to the head of the fibula (HF). Canella et al. (2009) were able to identify the location with ultrasound on healthy adult volunteers, but did not quantify its position in this manner. Others have also assessed this point on cadavers, but the clinical utility of these studies is again compromised by a lack of standardization for patient (fibular) size (Adkison et al., 1991; Ribak et al., 2016; supplementary file). These observations led us to investigate the anatomy of the SPN, to aid targeted deposition of local anesthetic when performing an ankle block.

The aim of this work was to define a landmark one may use to locate the SPN during an ankle block (i.e. where it pierces the deep fascia in relation to surrounding bony landmarks), which could be reproducibly identified on volunteers by ultrasound and in human cadavers by dissection.

Based on available literature and our observations from clinical practice, we hypothesized that the SPN pierces the deep fascia in the lower half of the leg, anterior or posterior to a point approximately one third of the distance along a straight line from the LM to the HF.

Materials and Methods

Ethical approval for this study was provided by the University of St Andrews, School of Medicine, Ethics Committee (MD13364). Cadaveric donors were identified from the University of St Andrews, School of Medicine, bequest program. Written permission was granted by the donor at the time of registering, as documented on the bequest declaration form, for their body to be made available for anatomical education, training and research. The cadaveric study was also conducted in accordance with the Anatomy Act (1984), as amended by the Human Tissue Act (Scotland) 2006, under the auspices of the Senior Licensed Teacher of Anatomy at the School of Medicine, University of St Andrews, UK.

Ultrasound cohort

Twenty-six volunteers were recruited, staff and students at the University of St Andrews, with written informed consent, giving a total of 52 lower limbs. Thirteen were male and 13 female, with a mean age of 27.85 years (min-max range 20-78 years; SD±13.186; 95% CI 24.18-31.52). To ensure anonymity of participants to the investigators, considering that volunteers may have been colleagues and/or students, information was not collected on race or ethnic background. No participants had a history of lower limb pathology affecting the SPN.

Participants were exposed below the knee, then the most prominent point on the bony landmarks of the HF and LM were marked. A straight line was drawn on the skin between these two points, in the distal half of the leg (fig 1). The leg was subsequently scanned using a 6-12 MHz linear array ultrasound probe (LOGIQ V2; GE Healthcare). The probe was initially placed anterior to the lateral malleolus and moved proximally until the SPN was identified. The SPN was then followed to the point of interest: the point at which it lay immediately above the deep fascia, having just emerged through it. The image was

acquired by one investigator (AT or JH; anesthetists), with the gain and depth adjusted to achieve optimal image resolution and focus. A second investigator (CG; expert regional anesthetist) then reviewed the images to verify findings. At this location, the probe was manipulated to position the SPN in the center of the screen, and the mid-point of both long and short axes on the ultrasound probe were marked on the skin. When the probe was removed, the marks were joined to form a cross, with a visually estimated perpendicular line drawn horizontally backwards from this to bisect the LM-HF line. The distance of the LM-HF line was measured (measurements rounded to the nearest millimetre), as was the distance from the LM to the point where the bisecting line crossed the LM-HF line. With these data, a ratio of the two distances was calculated. Finally, the distance the point of interest lay anterior or posterior to the LM-HF straight line was recorded.

Cadaveric cohort

This component used both lower limbs of 16 supine formalin-fixed cadavers: 8 male and 8 female, with a mean age of 82.88 years (min-max range 70-98 years. SD±6.964, 95% CI 80.36-85.39). All were embalmed using Vickers Cambridge mix©. None had any reported pathology or medical intervention with potential to alter the anatomy of the SPN.

Cadaveric work was undertaken by different investigators (JB and FC) to those who collected ultrasound data. Skin over the anterior and lateral compartments of the leg was reflected laterally from the anterior border of the tibia to a line posterior to the intermuscular septum between the lateral and posterior compartments. This exposure continued as far inferiorly as the intermalleolar line. Skin and superficial fascia over the HF and LM was also removed, so the bony prominences could be clearly identified. The superficial fascia was carefully explored to reveal the SPN, and its branches, as it emerged through the deep fascia; it was then followed inferiorly to the level of the intermalleolar line.

The most prominent points of the HF and LM were marked, then the distance between them was measured (again rounded to the nearest millimetre). Next, the distance from the LM to the point at which the SPN emerged from the deep fascia was measured. As with the ultrasound technique, the distance was recorded to a line, visually estimated to be perpendicular to the point of emergence, bisecting the LM-HF baseline (fig 2). Finally, the distance of this point anterior or posterior to the LM-HF baseline was again measured.

Data analysis

Two independent researchers (KT and OV), neither of whom was involved in data collection to eliminate potential researcher bias and ensure blinding, separately calculated the ratio and conducted the statistical analysis (supplementary file). Three recordings were taken for the cadaveric measurements and the average of these was used. Data were coded with all analyses performed in the IBM SPSS® software version 24. Due to data outliers, skewness and the relatively small sample size (<50) non-parametric tests were conducted (Ghasemi and Zhadiesi, 2012). The Mann-Whitney U test was used to assess the medians of continuous unpaired numerical data with exact, rather than asymptotic, p values reported due to the small dataset (Gray and Kinnear, 2007).

Results

Ultrasound cohort

The SPN was identified and measurements obtained in 100% of cases (n=52), none were seen to emerge through the deep fascia in more than one location. The mean LM-HF length was 36.32 cm (SD±2.981; 95% CI 35.49-37.15). The mean distance from the LM to the bisecting line, the level at which the SPN pierced the deep fascia, was 11.30 cm (SD±2.725; 95% CI 10.54-12.06). The mean ratio of these two distances was 0.31 (SD±0.066; 95% CI 0.29-0.33). The point of interest always lay on or anterior to the LM-HF line in all cases, by a mean distance of 0.74 cm (SD±0.624; 95% CI 0.56 - 0.91).

Cadaveric cohort

The SPN was identified and measurements obtained in 100% of cases (n=32). The SPN showed anatomical variability in 46.88% (n=15 limbs), including dividing deep to the deep fascia and emerging at two locations (fig 3). In these cases the main trunk of the SPN was used for measurements. The mean LM-HF length was 34.29 cm (SD±2.671; 95% CI 33.32-35.25). The mean distance from the LM to the bisecting line, was 10.46 cm (SD±2.434; 95% CI 9.58-11.34). The mean ratio was 0.30 (SD±0.062; 95% CI 0.28-0.33). The point of interest lay a mean distance of 1.51 cm (SD±0.509; 95% CI 1.33-1.70) from the LM-HF straight line, anterior in all cases.

Statistical analysis

A Mann-Whitney U test showed no statistically significant difference in the ratio between the two cohorts (U=764.000; exact 2-tailed p=0.534), however the point of emergence was found to lie further anterior to the LM-HF line in the cadaveric cohort (U=257.700; exact 2-tailed p<0.001).

Discussion

Many patients presenting for foot and ankle surgery suffer from chronic pain, and foot surgery is itself painful. An ankle block targets nerves supplying the foot above the level of the malleoli, beyond which they provide limited motor supply. It therefore provides excellent pain relief with minimal motor blockade, which can facilitate ambulatory surgery and early hospital discharge (Kopp and Horlocker, 2010; Purushothaman et al., 2013; Grant and Raju, 2016). Optimal post-operative analgesia may also reduce the development of chronic post-surgical pain (Remérand et al., 2014). Block failure can result in a more complicated intra-operative course for foot and ankle surgery, requiring greater medical intervention (Chin et al., 2001), and the benefits described above may not be obtained. Recent evidence suggests anatomical variation may be greater than is appreciated in clinical practice (Keplinger et al., 2018) and may contribute to this issue. The authors believe that variation in the SPN site targeted during an ankle block, the point at which it pierces the deep fascia, may contribute to an incomplete or failed block.

We have demonstrated that the main trunk of the SPN can be reproducibly identified just anterior to a point along a straight line from the LM to HF: 0.31 (31%; SD±0.066; 95% CI 0.29-0.33) of the distance on ultrasound and 0.30 (30%; SD±0.062; 95% CI 0.28-0.33) in dissected cadavers. These findings are consistent with cadaveric work previously published by Pacha et al. (2003). This information may assist the regional anesthetist in locating the SPN as the landmarks we have described can be used to focus the site of ultrasound scanning. This is particularly useful when imaging is compromised by excessive sub-cutaneous tissue or fluid in patient groups (morbidly obese, arteriopaths and those with heart failure) who stand to benefit the most from successful regional nerve block and avoidance of general anesthesia.

The finding that the SPN may divide before emerging form the deep fascia is not new and the variability in this pattern we found in cadavers is consistent with previous literature, although the frequency of type 2 branching in our cadaveric cohort is higher than the 15.6% in a recent meta-analysis by Tomaszewski et al. (2017) (fig 3).

However, knowledge of this variation commonly fails to transfer to descriptions that inform clinical practice, as evidenced by the lack of scrutiny in the anatomy summary of the ankle block description by Purushothaman et al. (2013). The discrepancy between the ultrasound and cadaveric cohorts in this aspect of the data is consistent with such a theory, but the significance of the data must be interpreted with caution. The investigators were not specifically asked to determine the number of points at which the SPN pierced deep fascia. Therefore, this difference may reflect inattention to this point when scanning rather than a difference in anatomy. Nevertheless, the discrepancy highlights that this information may potentially be missed in clinical practice if it not specifically sought. This, in turn, may play a role in failed ankle block, as part of the sensory supply to the dorsum of the foot may be preserved if not all branches of the SPN are identified and blocked.

Care must be taken when extrapolating these results to the population in general. The two cohorts in this study differed: an elderly cadaveric group and a predominantly young ultrasound group, both of unknown ethnicity (supplementary file). Also, though the SPN was identified, no assessment was undertaken to assess the extent of sensory supply lost when it is blocked. Therefore, even accurately identifying the correct nerve may not ensure complete and reliable anesthesia for the intended region (Keplinger et al., 2018). Measurements were taken to the nearest millimeter, although the bony landmarks are susceptible to a degree of interpretation. However, with no alternative method of improving

consistency of measurements, an element of pragmatism was applied to allow for translation of findings to clinical practice.

It will be important to further assess the ability to identify multiple (smaller) branches of the SPN piercing the deep fascia in different locations on ultrasound, as only by blocking all of these will the SPN be reliably blocked. Furthermore, a functional assessment of the territory supplied by the SPN (and therefore anesthetized during block) will further reinforce our understanding of the cause of failed ankle block.

In conclusion, these data demonstrate the utility of ultrasound in identifying the SPN, which was found to pierce the deep fascia of the leg just anterior to a point 30-31% along a straight line from the lateral malleolus to the head of the fibula. However, the findings highlight the need for knowledge of anatomical variation to be better transferred to clinical practice.

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Author contributions

JB: study concept and design, acquisition of data, data interpretation, drafting of manuscript, critical revision of manuscript, approval of article

KT: study design, recruitment of volunteers, data analysis/interpretation, critical revision of manuscript, approval of article

AT: study design, acquisition of data, critical revision of manuscript, approval of article

JH: acquisition of data, critical revision of manuscript, approval of article

FC: study design, acquisition of data, drafting of manuscript, critical revision of manuscript, approval of article

CG: study concept and design, acquisition of data, critical revision of manuscript, approval of article

OV: study design, data analysis/interpretation, drafting of manuscript, critical revision of manuscript, approval of article

Conflict of Interest

None declared.

Financial Disclosure

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Tables

Ratio		**Ultrasound Cohort (n=52)**	**Cadaveric Cohort (n=32)**
Mean		0.31	0.30
95% Confidence Interval for Mean	Lower Bound	0.29	0.28
	Upper Bound	0.33	0.33
Std. Error of Mean		0.009	0.011
Median		0.31	0.30
Variance		0.004	0.004
Std. Deviation		0.066	0.062
Interquartile Range		0.07	0.07
Skewness		0.569	0.844
Minimum		0.18	0.20
Maximum		0.53	0.46

Table 1. Descriptive statistics of calculated ratio (distance from LM to bisecting line/total distance of LM-HF line)

Figures

Figure 1. Ultrasound Methodology

A. An image of a volunteer's leg showing the markings made during the ultrasound identification of the superficial peroneal nerve. LM – lateral malleolus, HF – head of fibula, LM-HF – the line from lateral malleolus to the head of fibula, SPN – location of the superficial peroneal nerve emerging from the deep fascia; as determined by marking the long and short axis of the probe with the nerve in the centre of the picture.

B. An ultrasound picture showing the identification of the superficial peroneal nerve as it emerges from the deep fascia. This was the position of the probe when the markings in image A were made. EDL – extensor digitorum longus, DF – deep fascia, SPN – superficial peroneal nerve, PL – peroneus longus, PB – peroneus brevis, F – fibula.

Figure 2. Cadaveric Methodology

An image of a cadaveric left leg. The skin and superficial fascia have been removed to reveal the superficial peroneal nerve (SPN) emerging from the deep fascia. The lateral malleolus (LM) and head of fibula (HF) are marked by colored pins, and a tape measure used to measure the distance between them. This line is the equivalent of the marked LM-HF line used in the ultrasound cohort.

Figure 3. Variation in SPN morphology found during dissection.

A) SPN emerging from deep fascia as single trunk. B) SPN emerging as two branches. C) SPN emerges as a number of branches, one branch re-enters deep fascia before re-emerging distally. D) A window in the deep fascia shows the position of the SPN, a minor cutaneous branch emerges here and the main trunk emerges distally.

In all images the colored pin is the location of the lateral malleolus.

A. The most common appearance of the SPN (n=16). A single trunk emerges from the deep fascia and travels inferiorly before branching into the dorsum of the foot. This corresponds to Tomaszewski et al. (2017) description of a Type 1 pattern.

B. The most common variation seen in our study (n=12). The SPN emerges separately as two distinct branches. This corresponds to Tomaszewski et al. (2017) description of a Type 2 pattern. Also seen here is a small recurrent cutaneous branch heading proximal to the emergence.

C. An unusual appearance of the SPN (unilaterally in one cadaver). Two trunks and a minor cutaneous branch are present at emergence. The posterior branch then re-enters the deep fascia before re-emerging distally.

D. An unusual appearance of the SPN (unilaterally in one cadaver). A window appears in the deep fascia with the SPN lying in the floor. A minor branch emerges while the main trunk continues below the fascia. The minor branch continues inferiorly to where it recombines with the main trunk at its emergence.

(N.B. In two cases, the SPN emerged as a single trunk but did not branch, described by Tomaszewski et al (2017) as a Type 3 pattern.)