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Original Research

The Use of Ultrasonography to Identify the Intersection of the Dorsomedial Cutaneous Nerve of the Hallux and the Extensor Hallucis Longus Tendon: A Cadaveric Study

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ABSTRACT

Terminal branches of the superficial fibular nerve are at risk of iatrogenic damage during foot surgery, including hallux valgus rigidus correction, bunionectomy, cheilectomy, and extensor hallucis longus tendon transfer. One terminal branch, the dorsomedial cutaneous nerve of the hallux, is particularly at risk of injury at its intersection with the extensor hallucis longus tendon. Iatrogenic injuries of the dorsomedial cutaneous nerve of the hallux can result in sensory loss, neuroma formation, and/or debilitating causalgia. Therefore, preoperative identification of the nerve is of great clinical importance. The present study used ultrasonography to identify the intersection between the dorsomedial cutaneous nerve of the hallux and the extensor hallucis longus tendon in cadavers. On ultrasound identification of the intersection, dissection was performed to assess the accuracy of the ultrasound screening. The method successfully pinpointed the nerve in 21 of 28 feet (75%). The sensitivity, positive likelihood ratio, and positive and negative predictive values of ultrasound identification of the junction of the dorsomedial cutaneous nerve and the extensor hallucis longus tendon were 75%, 75%, 100%, and 0%, respectively. We have described an ultrasound protocol that allows for the preoperative identification of the dorsomedial cutaneous nerve of the hallux as it crosses the extensor hallucis longus tendon. The technique could potentially be used to prevent the debilitating iatrogenic injuries known to occur in association with many common foot surgeries.

Damage to the cutaneous nerves and subsequent sensory neuromas are common complications of foot and ankle surgery (1–6). The terminal branches of the superficial fibular (peroneal) nerve (SFN) are at risk of injury during operations of the hallux and metatarsophalangeal joint, including hallux valgus correction, hallux rigidus correction, bunionectomy, and cheilectomy (7,8). Likewise, extensor hallucis longus (EHL) tendon transfer, ankle arthroscopy, and injection procedures can jeopardize the branches of the SFN (9,10). Iatrogenic injuries often result in sensory loss, neuroma formation, and/or debilitating causalgia (8–11). Therefore, the surgical relevance of these nerves warrants a thorough understanding of their anatomy.

Typically, the SFN divides in the distal leg to form the medial and intermediate cutaneous nerves; however, numerous variations exist, including the absence of the medial and intermediate cutaneous nerves (11–16). At the dorsal foot, the medial cutaneous nerve divides to form the dorsomedial cutaneous nerve of the hallux (DMCN), also known as the proper dorsal digital nerve to the great toe (1,13), a nerve specifically vulnerable to injury during surgeries in the region of the metatarsophalangeal joint (7). The DMCN travels superficial to the tendon of the EHL before terminating near the distal dorsomedial aspect of the first metatarsal (8,17). Solomon et al (11) reported that the DMCN independently supplies the cutaneous innervation to the medial aspect of the great toe in 100% of cases (68 of 68 feet) and cutaneous innervation to the lateral aspect of the great toe and medial

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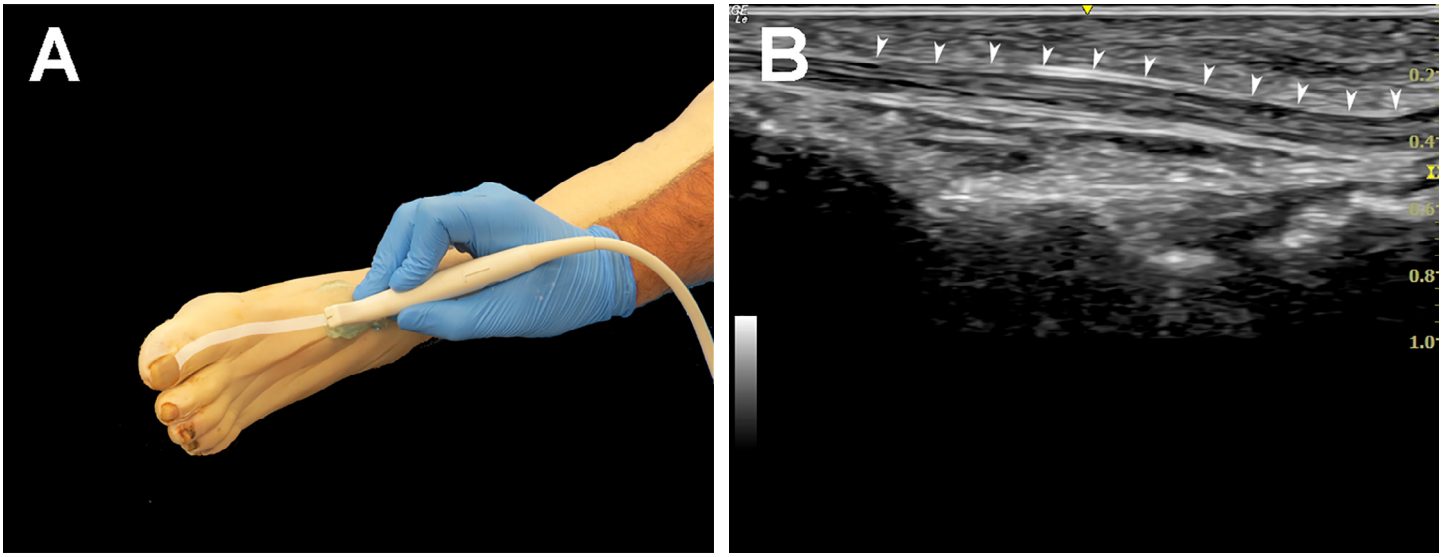

Fig. 1. Identification of the extensor hallucis longus (EHL) tendon using ultrasonography. The EHL is a reliable surface anatomic landmark that can be visualized easily in vivo by having a patient dorsiflex their great toe. Likewise, the EHL can be visualized in vivo and in cadaveric feet with little effort using ultrasonography. *(A)* Photograph of the hockey-stick probe position. The long axis of the probe is oriented with the long axis of the tendon to produce a longitudinal cross-sectional image. The position of the tendon is represented by a translucent white line. *(B)* Ultrasound image of the EHL tendon in longitudinal section corresponding to the probe position shown in *A* (*white arrowheads* indicate superficial surface of the EHL tendon).

aspect of the second digit in conjunction with the deep fibular nerve in 41% and 47% of feet, respectively.

Miller and Hartman (8) reported that the intersection of the DMCN and lateral border of the EHL tendon was an average of 32 (range 8 to 50) mm from the center of the first metatarsocuneiform (MTC) joint. Miller and Hartman (8) also noted that the intersection of the DMCN and medial border of the EHL tendon was 16 (range 0 to 41) mm proximal to the first MTC joint. Solan et al (17) documented that the DMCN crosses the EHL tendon (without specifying the medial or lateral aspect of the tendon) at a mean distance of 7.8 (range 0 to 16) mm proximal to the MTC joint.

With both the likelihood of anatomic variation and the surgical importance of the DMCN, imaging studies should be used to assess the anatomy of the SFN and its branches, in particular, the DMCN, before surgery. The objective of the present cadaveric study was to compare the predicted location of the DMCN, determined using ultrasonography, with the exact location of the DMCN determined by dissection.

Materials and Methods

The West Virginia State Anatomical Board (Morgantown, WV) approved the present research. A total of 14 cadavers were selected for the study, including 8 males (57.1%) and 6 females (42.9%). The mean average age at death of the cadavers was 75 ± 9.2 years.

A GE Venue 40 (GE Healthcare, General Electric Company, Boston, MA) ultrasound machine was used for ultrasonography (USG), in conjunction with an L8-18i wide-band high-frequency linear array transducer (6.7 to 18.0 MHz) set at a frequency of 15 MHz. All 28 feet of the 14 intact (i.e., not dissected) cadaveric specimens were examined. A first-year medical student with introductory-level experience in USG (K.D.M.) performed all ultrasound examinations in the present study.

The cadavers were positioned supine with the legs in full extension. The EHL tendon was first identified at the dorsum of the foot by USG in the long axis (Fig. 1). The EHL tendon was then followed in the long axis proximally to the approximate location of the DMCN. The location of the DMCN was assumed to be approximately 0 to 50 mm proximal to the MTC joint, as described previously (8,17). Because the DMCN crosses over the EHL tendon obliquely from the tendon's proximal and lateral border to its distal and medial border, the transducer was rotated (θ-y rotation) to locate the DMCN in its long axis (Fig. 2).

To check the accuracy of the DMCN location, a cruciate incision was made through the skin according to the midpoint markers on the L8-18i probe (Fig. 3). Therefore, the intersection of the cruciate incision corresponded to the midpoint marker on the ultrasound display. The 4 flaps of skin resulting from the cruciate incision were reflected to compare the location of the DMCN predicted by USG to the actual location of the DMCN (Fig. 4). Successful mapping of the DMCN was gauged in binary fashion. If the DMCN was located directly beneath the center of the cruciate incision described, the use of USG was considered successful.

Results

The DMCN was identified using USG in all 28 feet (100%); however, dissection revealed that the nerve was present at the intersection of the cruciate incision in 21 of the 28 feet (75%; 11 left feet [52.4%] and 10 right feet [47.6%]; Table). Thus, the test evaluation noted 21 true-positive results and 7 false-negative results. No false-positive or true-negative results were found; therefore, the specificity could not be calculated. The diagnostic sensitivity was 75% (95% confidence interval 55.13% to 89.31%), positive likelihood ratio was 75%, positive predictive value was 100%, and negative predictive value was 0%.

Discussion

Very few studies have used anatomic landmarks to approximate the location at which the DMCN obliquely intersects the EHL tendon. However, these studies have agreed that the branching pattern and distribution are highly variable, making it difficult to predict the intersection point of the DMCN and EHL tendon accurately (8,17). The present study was the first to use USG to predict the DMCN location

Table
Summary of test accuracy regarding ultrasound identification of dorsomedial cutaneous nerve of the hallux relative to identification using dissection (N = 28 feet in 14 cadavers)

Dissection Identification of DMCN	Ultrasound Identification of DMCN	
	Yes	No
Yes	21/28	0/28
No	7/28	0/28

Abbreviation: DMCN, dorsomedial cutaneous nerve of the hallux.