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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

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technique could potentially be used to prevent the debilitating iatrogenic injuries known to occur in association with many common foot surgeries.

Keywords

anatomy; great toe; orthopedics; podiatry; tendon transfer; ultrasound

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 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 wideband 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 and compare the predicted location with the actual location confirmed by dissection.

The DMCN of the hallux is at a particularly high risk of injury during surgical procedures involving EHL tendon transfers or tenodesis to correct hallux varus deformity (18–22), equinovarus foot deformity (23), clawed hallux associated with a cavus foot (24–26), and dynamic hyperextension of the hallux (27). These procedures require exposure of the EHL tendon with either complete or partial tendon transfer elsewhere in the foot to correct for various structural deformities and imbalances (18,20,28). Common procedures include the modified Jones procedure, McBride procedure, and ledge tenodesis (18,24,29–31), all of which can compromise the DMCN as it courses over the EHL tendon.

Other procedures, including correction of hallux valgus, hallux varus, hallux rigidus, first metatarsal osteotomies, EHL repair, and open reduction and internal fixation of midfoot fractures or dislocations, also involve isolation of the EHL tendon and incisions along its borders, placing the DMCN at risk (13). Tremendous variation exists in these surgical techniques, with >130 operative approaches described for the treatment of hallux valgus alone (32).

Iatrogenic damage to the DMCN can be painful, debilitating, and very difficult to treat (1). In a study of 51 patients who had undergone surgery of the hallux, Campbell (7) reported sensory loss in 45% of the feet examined. Of these patients, 29% were aware of their symptoms, and 3% reported severe and disabling symptoms. In a separate series, Meier and Kenzora (33) reported an incidence of nerve damage as great as 30%. The term “DMCN syndrome” has been suggested to describe the neuropathic condition that results from damage of the DMCN (8). Moreover, the sequelae from such nerve damage include trophic ulcerations at denervated areas of skin (7). Surgical complications can be minimized if care is taken to avoid damage to the DMCN during procedures involving the EHL tendon. However, in the event of DMCN nerve damage, the nerve could require resection and burial into bone—a procedure that risks further damage to the DMCN (34–36).

The results of the present study have demonstrated that USG is an accurate method to pinpoint the DMCN relative to the EHL tendon. Successful localization of this intersection was noted in 75.0% of the feet (21 of 28). The variability in the branching patterns of the SFN, in particular, of the DMCN branch, might have contributed to the false negatives in this study. Kosinski (12) noted that the DMCN was absent in 1.7% of feet, in which case the region normally supplied by the DMCN was innervated by the saphenous nerve. In contrast, in the absence of the DMCN, supernumerary DMCNs could be present. Solomon et al (11) reported a prevalence of duplicated DMCNs in 2.9% of feet (2 of 68). The investigators noted duplicated DMCNs crossing the EHL tendon on cadaveric dissection. An image of duplicated DMCNs crossing the EHL is shown in Fig. 5. To the best of our knowledge, Fig. 5 represents the first photograph of duplicated DMCNs to be reported in the scientific data. Therefore, the existence of duplicated DMCNs could have contributed to operator error in their study and might, like-wise, lead to confusion in the clinical setting (11). Because the entirety of the superficial fibular (peroneal) nerve and its branches were not dissected in their

study, the absence of the DMCN branch or supernumerary branches could have contributed to false-negative results (11).

Despite the occurrence of either absence or duplication of DMCNs in 1.7% and 2.9%, respectively, the present study has shown that a first-year medical student with introductory-level experience can successfully identify the intersection of the DMCN with the EHL using USG in 75% of the feet examined. Therefore, the success rate should likely improve when USG is performed by surgeons and clinicians with more experience in USG. However, even experienced clinicians should be aware of the potential for anatomic variations in the DMCN that can contribute to difficulty in identifying the DMCN. The greatest limitations of our investigation were probably the variability of the anatomy and, perhaps, differences in the response of the ultrasound instrumentation in cadaveric specimens compared with living, breathing patients.

In conclusion, USG provides an inexpensive, accurate, noninvasive method of preoperatively identifying the location of the DMCN relative to the EHL tendon. Successful identification of the DMCN using USG can be used to prevent debilitating iatrogenic nerve damage during foot surgery.

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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).

Fig. 2.

Identification of the dorsomedial cutaneous nerve of the hallux (DMCN) using ultrasonography. The DMCN presents with the typical “bundle-of-straws” appearance—hyperechoic linear fascicles with intervening echogenic interfascicular perineurium. (A) Photograph of the hockey-stick probe position. The long axis of the probe is oriented with the long axis of the DMCN to produce a longitudinal cross-sectional image. The position of the DMCN is represented by a *translucent yellow line*. (B) Ultrasound image of the DMCN tendon in longitudinal section and the EHL tendon in oblique section corresponding to the probe position shown A (*yellow arrowheads* indicate DMCN; *white arrowheads*, deep surface of the EHL tendon).

Fig. 3. Photograph with superimposed *dotted lines* that identify the location of the cruciate incision used to confirm the location of the dorsomedial cutaneous nerve of the hallux (DMCN) by direct observation. The *dotted lines* correspond to the midpoint markers on the hockey-stick probe. The hockey-stick probe is oriented such that the long axis of the DMCN is visualized in its longitudinal section and the EHL is in oblique section corresponding to that shown in Fig. 2.

Fig. 4.

Photograph of the dorsal surface of the left foot of a cadaver. A cruciate incision was made (as shown in Fig. 3), and the 4 skin flaps created by the incision were reflected. The intersection point of the incisions corresponded to the location of the dorsomedial cutaneous nerve of the hallux (DMCN).

Fig. 5.
Dorsal view of a left foot with duplication of the dorsomedial cutaneous nerve of the hallux. The dorsomedial cutaneous nerves (*stars*) can be seen crossing the extensor hallucis longus tendon (*circle*) in multiple locations.

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.