Clinical Anatomy

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CLINICAL ANATOMY

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Topographical Anatomy of the Superficial Peroneal Nerve: A Cadaveric Study on Anatomical Patterns and Clinical Implications

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Received: 8 January 2025 | **Revised:** 17 March 2025 | **Accepted:** 26 March 2025

Keywords: anatomical | anatomical variation | ankle surgery | cadaveric study | foot surgery | landmarks | lower extremity nerve anatomy | peripheral nerve injuries | superficial peroneal nerve | surgical landmarks

ABSTRACT

The notable anatomical variability of the superficial fibular nerve (SFN) affects clinical and surgical procedures that involve it. The aim of this study was to analyze the course and branching patterns of the SFNs relative to bony landmarks to provide foundational data for surgical precision and thereby minimize iatrogenic injuries. Thirty-four embalmed Korean cadavers were dissected. The points at which the SFN (1) pierced through the crural fascia and (2) bifurcated into the medial and intermediate dorsal cutaneous nerves were measured from the lateral malleolus and fibula. The SFN piercing point was located at an average of 89.6 ± 30.8 mm (range: 26.5–153.8 mm) above the lateral malleolus and 14.7 ± 3.6 mm (range: 7.1–21.5 mm) horizontally from the fibula. In 32 specimens, the SFN pierced the fascia and then bifurcated, but in the other two cases it bifurcated before piercing the fascia. The bifurcation point was identified at an average height of 40.8 ± 20.1 mm and a horizontal distance of 25.1 ± 7.5 mm from the fibula. There was significant anatomical variability in the trajectory and branching patterns of the SFN. These findings underscore the importance of precise anatomical knowledge for minimizing complications during foot and ankle surgeries. This study provides a foundation for preoperative planning and clinical application around the SFN.

1 | Introduction

The superficial fibular nerve (SFN) is one of the two terminal branches of the common fibular nerve, originating in the lateral compartment of the lower leg. It innervates the muscles in this compartment and provides sensory innervation to the skin of the dorsum of the foot. As the SFN descends, it becomes superficial near the midleg and branches into the medial and intermediate dorsal cutaneous nerves, which innervate the skin on the dorsum of the foot and toes (Standring 2021). This is considered normal anatomy, but the SFN often shows significant anatomical variations (Blair and Botte 1994; Canovas et al. 1996). These variations are important during foot and ankle surgeries, arthroscopic procedures, and ankle block anesthesia, where precise knowledge of the sensory branches of the SFN is crucial for avoiding complications (Şayli et al. 1998).

The SFN is susceptible to injury from trauma or surgical interventions on the lateral aspect of the leg, which can lead to sensory loss in the dorsum of the foot and weakened foot eversion. Owing to its importance as a landmark for neurolysis, compartment release, open reduction and internal fixation,

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and muscle flap procedures, surgeons must be acutely aware of its location to avoid iatrogenic injury and to locate it efficiently during surgery (Ducic et al. 2006). Autologous nerve grafts are essential for bridging large nerve gaps following trauma. The commonly used grafts include the sural, superficial radial, and medial cutaneous nerves of the upper extremities. In cases requiring multiple or long nerve grafts, the femoral cutaneous nerves of the thigh and the SFN are also used (Agthong et al. 2008). Notably, the SFN has been successfully used as a nerve graft with outcomes comparable to those of the sural nerve (Buntic et al. 2002).

Superficial sensory branches are vulnerable to injury from cuts and surgical incisions, which can cause crippling symptoms, excruciating post-surgical pain, and challenging recovery (Miller and Hartman 1996; Ucerler and Ikiz 2005). Despite careful surgical procedures, the risk of nerve injury persists, highlighting the need for precision based on anatomical knowledge (Apaydin et al. 2008). Understanding how the SFN varies in piercing the crural fascia is crucial for avoiding iatrogenic injury (Henry et al. 2016; Tomaszewski et al. 2017). Various clinical and surgical procedures are performed around the foot and ankle, including compression bandaging, plastering, selective anesthetic block, fasciotomy for compartment syndromes, ankle arthroscopy, percutaneous pin or screw placement for external fixation, tibial nailing, the lateral ankle approach for fibular osteosynthesis, and ankle arthrodesis or arthroplasty. Given the highly variable location and branching pattern of the SFN, there is a considerable risk of iatrogenic lesions during such procedures, which can cause debilitating symptoms such as numbness, paresthesia, and/or pain (Bowness et al. 2019; Darland et al. 2015). Saito and Kikuchi (1998) found that the SFN was injured in four of 16 ankle arthroscopy cases, indicating that peripheral nerve injuries are not uncommon in these procedures. Complication rates for ankle arthroscopy range from 0.9% to 17%, with SFN injuries accounting for a significant proportion of these cases (Ucerler and Ikiz 2005). Furthermore, neuromas resulting from SFN transactions have been reported during ankle fracture surgery (Redfern et al. 2003). Careful attention is required to avoid injuring the SFN during surgical procedures.

However, previous studies have not clarified the exact location, height, and distance at which the SFN pierces the crural fascia. Therefore, the aim of this cadaveric study was to measure the relationship between the SFN and established bony landmarks and to describe its branch patterns. Another aim of the study was to provide an evidence-based assessment of the anatomical variants of the SFN division. This will help to develop a clinically useful classification system and improve treatment plans and risk assessments for procedures in the distal leg and foot regions.

2 | Materials & Methods

We examined the morphological patterns of the SFN using 34 calves of embalmed Korean cadavers (male, 21; female, 13). The cadavers were legally donated to Yonsei Medical Center (Seoul, Republic of Korea) and dissected following approval from the Surgical Anatomy Education Center at Yonsei University College of Medicine.

The skin of the anterolateral region of the calf was removed and the subcutaneous tissues were separated to locate the point at which the SFN pierces the crural fascia. The nerve was carefully traced downward to its terminal branches to ensure that its course remained intact throughout the procedure. The most prominent point on the lateral malleolus of the fibula was used as the primary reference for measurements. The height of the SFN piercing point was recorded as the vertical distance from the lateral malleolus to the location where the nerve pierced the crural fascia; the horizontal distance to the fibula was also measured. Additionally, the bifurcation point of the SFN into the medial and intermediate branches was identified and its position relative to the lateral malleolus and fibula was recorded (Figure 1). Further measurements included the distance from the lateral malleolus to the medial and intermediate dorsal cutaneous nerves, and, where applicable, the locations of secondary branching points. Subsequently, the branching patterns of the SFN were analyzed and categorized. Given the inherent limitations of cadaveric studies, which constrain sample size, the aim of the analysis was to identify anatomical trends rather than establish statistical significance.

Statistical analyses were conducted to examine sex differences in the anatomical measurements of the SFN. The Shapiro–Wilk test was used to assess the normality of the data. Independent sample t-tests were then used to compare the means between sexes. A p value <0.05 was considered statistically significant. SPSS software (version 23.0 for Windows, SPSS, Chicago, IL, USA) was used for all statistical analyses.

3 | Results

The SFN showed notable anatomical variability in its course and branching patterns. Measurements revealed several key characteristics of nerve morphology and spatial relationships. The point at which the SFN pierced through the crural fascia was located at an average height of 89.6 ± 30.8 mm from the lateral malleolus (range: 26.5–153.8 mm) and a horizontal distance of 14.7 ± 3.6 mm from the fibula (range: 7.1–21.5 mm). These measurements varied notably among the specimens. Figure 2 shows the variability in the piercing point of the SFN.

The division of the SFN into its medial and intermediate branches was identified at an average height of 40.8 ± 20.1 mm from the lateral malleolus. The corresponding horizontal distances from the fibula to this bifurcation point averaged 25.1 ± 7.5 mm. Variations in these measurements reflect the diverse anatomical patterns of the SFN. The distance from the lateral malleolus to each branch was also measured. The intermediate dorsal cutaneous nerves extended to the middle dorsum at an average distance of 34.4 ± 8.2 mm from the lateral malleolus (range: 20.2–55.2 mm), while the medial dorsal cutaneous nerves were reached at an average distance of 47.2 ± 9.1 mm (range: 27.6–65.0 mm). A secondary branch of the medial dorsal cutaneous nerves was observed in nine cases, at an average distance of 51.1 ± 14.1 mm from the lateral malleolus. The detailed measurements are presented in Table 1.

No significant sex differences were observed in the piercing point height from the lateral malleolus, the piercing point

FIGURE 1 | Anatomical measurements of the superficial fibular nerve (SFN). The vertical and horizontal distances of the SFN piercing point from the lateral malleolus and fibula were measured. The bifurcation point of the SFN into medial and intermediate branches was also recorded relative to these landmarks.

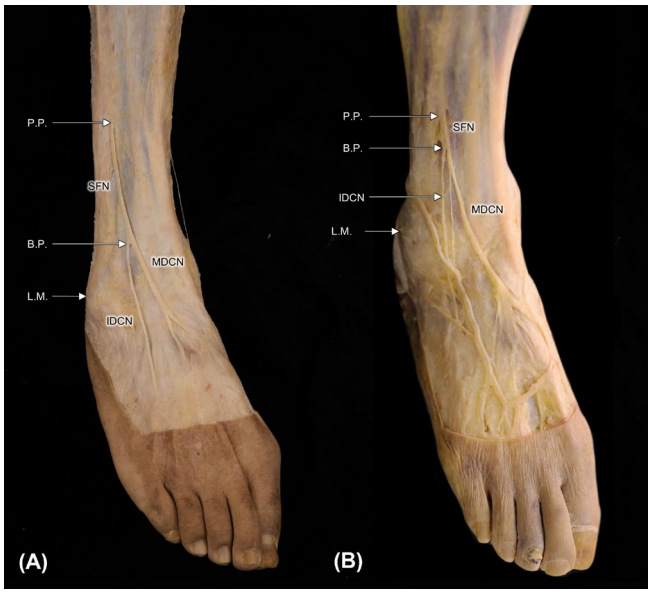

FIGURE 2 | Variations in the superficial fibular nerve (SFN) piercing point (P.P.) and bifurcation point. (A) Example of the SFN piercing the deep fascia and traveling a certain distance before bifurcating into the medial dorsal cutaneous nerve (MDCN) and intermediate dorsal cutaneous nerve (IDCN); (B) Example of the SFN bifurcating into the MDCN and IDCN immediately upon piercing the deep fascia.

distance from the fibula, the bifurcation point height from the lateral malleolus, or the bifurcation point distance from the fibula (Table 2). Nonetheless, there were variations in specific measurements. The piercing point height from the lateral malleolus was greater in males (mean: 97.8 ± 39.3 mm) than in females (mean: 82.7 ± 36.3 mm). The horizontal distance of the piercing point from the fibula was similar between males (13.7 ± 4.1 mm) and females (13.4 ± 3.2 mm). The bifurcation point height averaged 42.3 ± 3.8 mm in males and 46.39 ± 11.99 mm in females, while the horizontal distance was 24.3 ± 9.0 mm in males and 21.6 ± 2.1 mm in females. The distances to the medial dorsal cutaneous branch were generally greater in males (49.0 ± 8.1 mm) than in females (37.9 ± 5.7 mm). These findings highlight the potential individual variability in SFN anatomy.

4 | Discussion

The SFN is a key anatomical structure in the lower limb with dual roles in motor and sensory innervation. As one of the terminal branches of the common fibular nerve, it traverses the lateral compartment of the leg and becomes superficial, innervating the dorsum of the foot (Standring 2021). Its anatomical and clinical significance lies in its proximity to surgical sites and vulnerability to injury, making precise knowledge of its location and its variations essential for minimizing complications in procedures such as foot and ankle surgeries, neurolysis, and compartment release (Agthong et al. 2008; Miller and Hartman 1996; Şayli et al. 1998).

From a clinical perspective, the variability of the SFN is particularly relevant to procedures such as ankle arthroscopy and external fixation, where inadvertent injuries can lead to sensory loss or chronic pain (Bowness et al. 2019; Darland et al. 2015). Additionally, the SFN can be harvested for nerve grafting with minimal donor site impact owing to its limited sensory territory. Understanding branching patterns is critical

TABLE 1 | Measurement landmarks and distances related to the superficial fibular nerve.

	F.H. to L. M.	P.P. height from L. M.	P.P. distance from fibula	B.P. height from L. M.	B.P. distance from fibula	Distance to IDCN from L. M.	Distance to MDCN from L. M.	Distance to MDCN 2nd br. from L. M.
Min.	29.2	26.5	7.1	10.7	13.2	20.2	27.6	28.1
Max.	36.7	153.8	21.5	95.8	36.9	55.2	65.0	70.1
Mean	33.2 ± 2.2	89.6 ± 30.8	14.7 ± 3.6	40.8 ± 20.1	25.1 ± 7.5	34.4 ± 8.2	47.2 ± 9.1	51.1 ± 14.1

Note: This table summarizes the measurements obtained from dissected specimens, highlighting key anatomical landmarks and distances. Data are presented as mean ± standard deviation in millimeters (mm).
Abbreviations: B.P., bifurcation point; F.H., fibular head; IDCN, intermediate dorsal cutaneous nerves; L.M., lateral malleolus; Max., maximum value; MDCN, medial dorsal cutaneous nerves; Min., minimum value; P.P., piercing point.

TABLE 2 | Comparison of anatomical measurements of the superficial fibular nerve between sexes.

	Male ($n = 21$)	Female ($n = 13$)	p
P.P. height from L. M.	93.96 ± 25.28	80.72 ± 29.80	0.230
P.P. distance from fibula	15.50 ± 3.44	14.52 ± 3.69	0.493
B.P. height from L. M	42.23 ± 22.74	38.24 ± 14.84	0.660
B.P. distance from fibula	25.26 ± 7.90	24.84 ± 7.30	0.898

Note: Data are presented as the mean ± standard deviation in millimeters (mm).
Abbreviations: B.P., bifurcation point; L.M., lateral malleolus; P.P., piercing point.

for optimizing grafting techniques and avoiding damage during harvesting (Ribak et al. 2016). Previous studies have reported the location of the SFN; however, measurements differed significantly among populations from France, the United States, and India. Our findings, which are based on a Korean population, highlight regional anatomical differences (Praksh et al., 2010; Barrett et al. 2006; Canella et al. 2009). These knowledge gaps emphasize the necessity for meticulous preoperative planning and the integration of imaging techniques to identify the location and branching patterns of the SFN and thereby minimize the risk of iatrogenic injuries. Such findings would significantly enhance surgical precision and improve patient outcomes, reinforcing the critical role of anatomical understanding (Correia et al. 2022).

Our results showed that the SFN predominantly followed a pattern in which it pierced the fascia before bifurcating (94.1%). This finding aligns with Tomaszewski et al. (2017), who reported Type I as the most prevalent pattern across Asian and European populations. The piercing point was located at an average height of 84.75 mm from the lateral malleolus (range: 26.51–151.56 mm) and a horizontal distance of 14.68 mm from the fibula (range: 3.51–21.51 mm). The bifurcation point was identified at an average height of 41.30 mm from the lateral malleolus and a horizontal distance of 24.86 mm from the fibula. In one case, the intermediate dorsal cutaneous nerve emerged at a height of 34.83 mm and the medial dorsal cutaneous nerve at 102.63 mm. In another case, the intermediate branch pierced the fascia at 26.51 mm, whereas the medial branch emerged at 111.33 mm. The two cases demonstrated a notable difference in piercing height, the intermediate branch consistently emerging at a lower position and the medial branch at a higher position. In contrast, the SFN pierced the fascia first in most specimens, and then divided into its medial and intermediate branches after traveling a certain distance. These findings highlight the anatomical variability of the SFN and underscore its relevance in surgical planning.

This study has several strengths. By focusing on cadaveric dissections, we provide detailed and direct observations of the anatomical variability of the SFN, bridging the gap between anatomical research and clinical application. These findings provide foundational data for surgeons to minimize complications and improve patient outcomes. Additionally, the measurement of distances and landmarks provides quantifiable references that can guide surgical practice. The fibular head and lateral malleolus, which are easily palpable on the skin surface, serve as reliable landmarks for estimating the location of the fibula and related anatomical structures. According to our results, while the branching patterns of the SFN were variable, the nerve consistently followed a path 15–25 mm medial to the fibula. At the ankle, the superficial cutaneous branches of the SFN ran > 34 mm medial to the fibula.

However, this study has an inherent limitation in that it targeted only Korean populations. Moreover, the sample size was relatively small, and in only two specimens did the SFN bifurcate before piercing the fascia. In view of this limited dataset, establishing a definitive classification system for anatomical patterns would not be appropriate. Future studies should address these gaps by incorporating larger and more diverse sample populations and examining population-specific anatomical variations. Further research should also consider a classification of anatomical variations, particularly in populations with different ethnic backgrounds, to validate the rare bifurcation patterns observed in this study. Integrating advanced imaging techniques such as high-resolution ultrasound or three-dimensional imaging could complement the cadaveric findings by providing real-time anatomical mapping and enhancing preoperative planning. In this study, ultrasound imaging was used

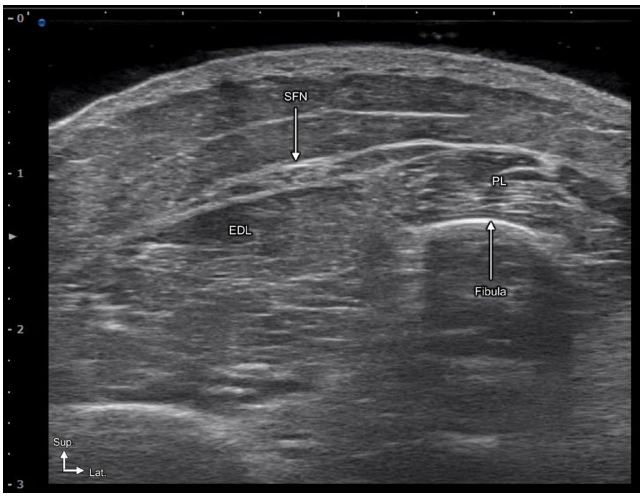

FIGURE 3 | Ultrasonographic image showing the superficial fibular nerve (SFN) emerging through the deep fascia at the piercing point. The SFN, which courses beneath the deep fascia, is visualized at the point where it transitions to the superficial layer between the fascial planes. SFN, superficial fibular nerve; EDL, extensor digitorum longus; PL, peroneus longus.

to visualize the trajectory and branching patterns of the SFNs, effectively bridging anatomical measurements and clinical imaging. The SFN was consistently identified using the fibular head and lateral malleolus as palpable landmarks. The average measurements derived from this study, such as the SFN coursing 15–25 mm medial to the fibula and > 34 mm from the lateral malleolus at the ankle, proved invaluable for precise probe placement. These findings underscore the practical utility of integrating anatomical data into ultrasound imaging for accurate localization of the SFN, facilitating safer clinical interventions and broadening its potential applications in diagnostic and therapeutic settings (Figure 3).

5 | Conclusion

In conclusion, this study provided detailed anatomical data on SFN variability, emphasizing its clinical significance and utility in surgical planning. By using surface anatomical landmarks, the findings offer a practical reference for clinicians and facilitate safer and more precise preoperative planning. Future research should expand the dataset, explore regional and demographic differences, and integrate advanced methods to enhance our understanding of SFN anatomy and its clinical applications.

Acknowledgments

This article exhibition was supported by Wonkwang University in 2025.

Ethics Statement

All authors were well-informed of the WMA Declaration of Helsinki—Ethical Principles for Medical Research Involving Human Subjects—and confirmed that this study firmly fulfilled the declaration. None of the authors has financial or private relationships with commercial, academic, or political organizations or people that may have improperly influenced this research.

Data Availability Statement

The data presented are available on request from the corresponding author.

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