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ORIGINAL ARTICLE

Branching patterns of the superficial fibular nerve: an anatomical study with meta-analysis

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Abstract

Purpose To review variations regarding the branching patterns of the superficial fibular nerve (SFN) concerning the deep fascia of leg and to the ankle joint level.

Methods Searches were conducted in PubMed, Scopus, Lilacs, and Web of Science databases on October 14th, 2021. We followed the PRISMA guidelines to report this review. Articles with data on SFN variations prevalence were included. The data were extracted and pooled into a meta-analysis. We also dissected 60 formalin-fixed Brazilian fetuses ($n=120$ lower limbs).

Results Twenty-five studies ($n=1272$ lower limbs) comprised this review. Concerning the SFN branching at the deep fascia, Type 1 variation (in which the SFN pierces the fascia as a single nerve trunk) had a pooled prevalence of 86.4% (95% CI 84.5–88.2), while Type 2 had a pooled prevalence of 13.6% (95% CI 11.8–15.5). At the ankle joint level, Type 2 variation (in which the SFN branches off below the joint level) was the most common anatomical pattern, with a pooled prevalence of 78.7% (95% CI 74.5–82.7).

Conclusion Typically, the SFN branches off between its exit from the deep fascia and the ankle joint level. The SFN variations have great importance for surgeries, such as arthroscopies and fascia release surgeries, regional anesthesia, and clinical evaluation of SFN entrapment syndrome.

Keywords Superficial fibular nerve · Anatomy · Anatomic variation · Meta-analysis

Introduction

The superficial fibular nerve (SFN) provides motor inputs to the fibularis longus and fibularis brevis muscles [16] and sensibility outputs of the anterolateral leg and dorsum of the foot [9]. The SFN arises from the branching of the common fibular nerve [38], travels through the lateral compartment of the leg [34], and reaches the dorsum of the foot after piercing the deep fascia of the leg to divide into two branches: the medial dorsal cutaneous (MDCN) and intermediate dorsal cutaneous (IDCN) nerves.

Regarding SFN variations, previous studies have reported many variations in SFN branching at the deep fascia and ankle joint level, which affect leg and foot surgeries. Knowing the SFN anatomy is essential to avoid SFN injury during ankle arthroscopy [3, 39], and injury to one of the terminal branches of SFN can lead to loss of leg skin sensation and chronic pain in the dorsum of foot [9]. In addition, possible unexpected nerve variations may impair regional anesthesia in the foot and leg; hence, incomplete or unsuccessful nerve blockades may occur, which inflict pain on the patients and prolong recovery time [6].

The branching patterns of SFN are relevant for clinical and surgical purposes; therefore, the present paper aims to provide a comprehensive, evidence-based systematic review with a meta-analysis and an original cadaver study on this topic.

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Materials and methods

Meta-analysis

Register and guidelines

Our review protocol review was approved by the International Prospective Register of Systematic Reviews (registry code: CRD42020207050). We conducted the present review in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21] and the guidelines by the International Evidence-Based Anatomy Working Group (iEBA-WG) [12].

Search strategy

The data were obtained from a literature survey on October 14th, 2021, in the PubMed, Scopus, Lilacs, and Web of Science databases. The searches in all electronic databases comprised combinations of the keywords "superficial peroneal nerve", "superficial fibular nerve", "anatomy", and "anatomical variation". No restrictions were imposed on the publication year, language, and study design. Reference lists of relevant articles were also searched.

Eligibility assessment

Two review authors examined the retrieved records for eligibility and solved disagreements via consensus. Anatomical studies on the SFN anatomy with no distinction of design or anatomical evaluation method (e.g., magnetic resonance imaging, ultrasound, intraoperative, and dissection) were deemed eligible for inclusion. Reviews, book chapters, conference abstracts, case reports or case series, and studies outside the review's scope were excluded after the reading of abstracts and full-text texts.

Data extraction

Two review authors extracted the following data from the primary studies: first authors' surname, location where the study was conducted, publication year, sample size, and amount of variations found in the study. In the present review, we evaluated the SFN branching in the leg (first variable) and ankle (second variable).

With respect to the SFN branching patterns in the leg, we classified the variations in the following way: Type 1, the SFN branches off after piercing the deep fascia; Type 2, the SFN branches off before piercing the deep fascia (Fig. 1).

With regard to the SFN branching patterns at the ankle joint level, the following classification system by Takao et al.

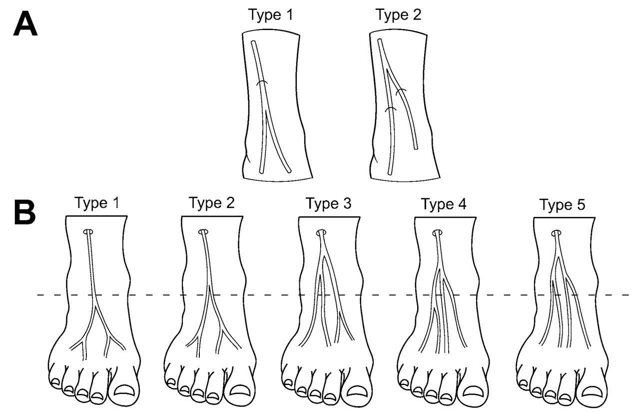

Fig. 1 Branching patterns of superficial fibular nerve in relation to the deep fascia (**A**) and the ankle joint (**B**). Right distal leg

[33] was adopted: Type 1, both the MDCN and IDCN branch off distal to the joint level; Type 2, the SFN branches off proximal to the joint, but its terminal nerves branches off distal to it; Type 3, the IDCN branches off proximal to the joint, but the MDCN branches off distal to it; Type 4, the MDCN branches off proximal to the joint, but the IDCN branches off distal to it; Type 5, both the MDCN and IDCN branch off proximal to the joint level (Fig. 1).

Statistical analysis

The present meta-analysis of prevalence was performed based on the random-effects model, with a 95% confidence interval (95% CI) and Freeman–Tukey double arcsine transformation [10, 19]. We used MetaXL software to analyze the data [4].

Cochran's Q test and Higgins's I^2 statistic were adopted to measure the heterogeneity among the primary studies. Subgroup analyses were performed by means of the Chi-square test to assess whether the geographical location influences SFN anatomy. P values of less than 0.05 were deemed statistically significant.

Anatomical study

Sample characteristics

We included fetuses aged from the fourth to the ninth months of conception without neural or non-neural deformities in their lower limbs. The fetuses were obtained from cadaver donation programs for anatomy research at our university. Sixty formalin-fixed Brazilian fetal cadaver specimens ($n = 120$ lower limbs), of which 30 were male and 30 were female, were used in this anatomical study. The race of the included fetuses could not be determined because of the tissue wasting caused by formaldehyde.

Dissection method

We dissected the anterior aspect of the leg and foot to expose the SFN branching (Fig. 2). We used No. 15 surgical scalpel blades and Metzenbaum scissors. The data were later collected and classified for further analysis, as well as stored by means of a photographic record.

Ethical considerations

We state every effort was made to follow all local and international ethical guidelines and laws regarding using human cadaveric donors in anatomical research, as recommended by Iwanaga et al. [15]. Ethical approval from the local Human Research Ethics Committee is included at the end of the paper.

Results

Identification of studies

Figure 3 displays the article identification process. A total of 827 records were retrieved from the searched electronic databases. After removing duplicates, 720 records were analyzed, of which 57 were deemed potentially eligible after

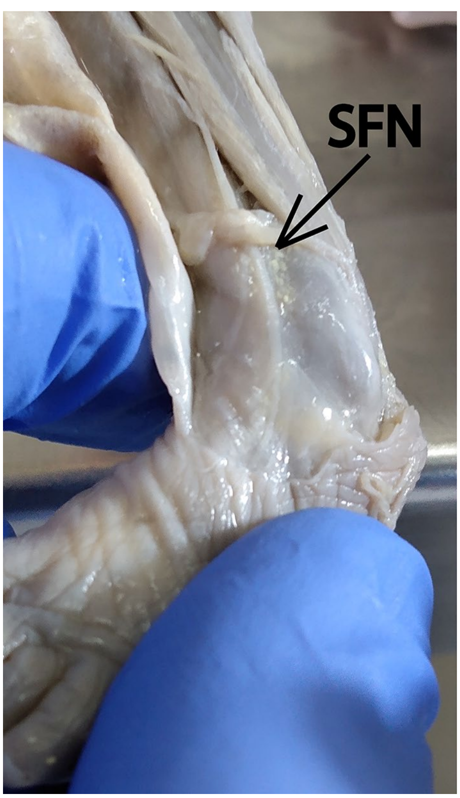

Fig. 2 Example of a dissected specimen (left lower limb, female)

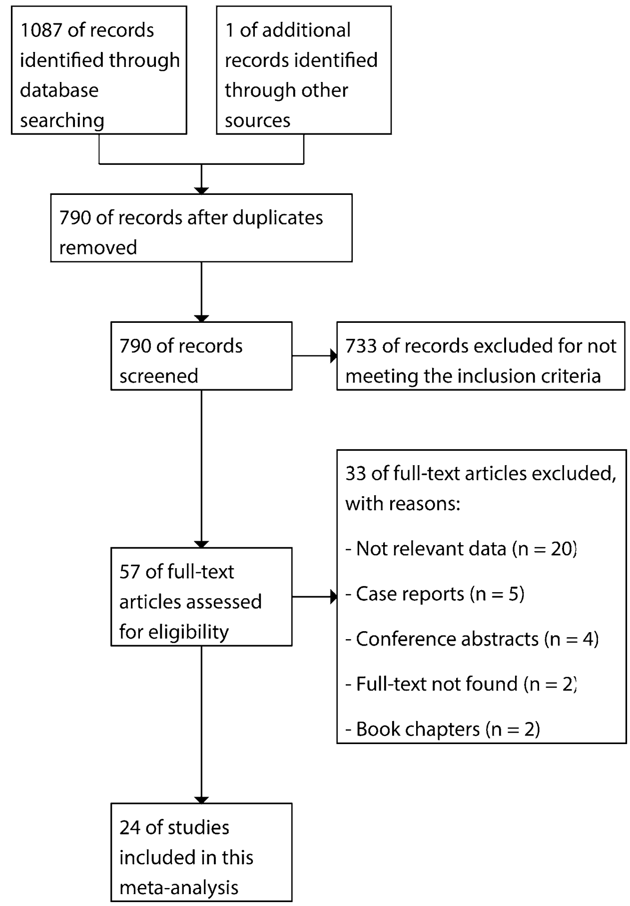

Fig. 3 Flowchart of study selection according to the PRISMA statement

reading titles. Thirty-three studies were excluded in compliance with the exclusion criteria. Twenty-four studies were included after the selection process.

Characteristics of included studies

Twenty-four studies were selected by means of the article identification process [1, 2, 5–9, 13, 17, 18, 22–31, 33, 35–37]. Considering the current cadaveric study, 25 studies composed the meta-analysis ($n = 1272$ lower limbs). The characteristics of the included studies are summarized in Table 1.

Results of the current cadaveric study

There was no statistically significant association between the side of the lower limb ($p = 0.327$) or sex of the fetuses ($p = 0.142$), with the variations in SFN branching when this nerve pierces the deep fascia. With regard to the SFN branching at the ankle joint level, no statistically significant association was found in terms of lower limb side ($p = 0.834$)

Table 1 Characteristics of the studies included in the current review

Authors	*n* (limbs)	Geographical location	Type[a]	Age[b]
Adkison et al. (1991) [1]	85	North America	C	A
Agthong et al. (2008) [2]	85	Asia	C	A
Blair and Botte (1994) [5]	25	North America	C	A
Bowness et al. (2019) [6]	28	Europe	C	A
Canella et al. (2009) [7]	65	Europe	C and U	A
Canovas et al. (1996) [8]	30	Europe	C	A
Darland et al., (2015) [9]	50	North America	C	A
Herron et al. (1993) [13]	20	Europe	C	A
Kosinski (1926) [17]	109	Europe	C	A
Kurtoglu et al. (2006) [18]	40	Asia	C	F
Ögüt et al. (2004) [22]	63	Asia	C	A
Olave et al. (2011) [23]	16	South America	C	A
Pacha et al. (2003) [24]	20	Europe	C	A
Prakash et al. (2010) [25]	60	Asia	C	A
Ribak et al. (2016) [26]	10	South America	C	A
Rodríguez-Lorenzo et al. (2011) [27]	9	Europe	C	A
Saito e Kikuchi (1998) [28]	104	Asia	C	A
Şayli et al. (1998) [29]	29	Asia	C	A
Solomon et al. (2006) [30]	68	Oceania	C	A
Solomon et al. (2001) [31]	68	Oceania	C	A
Takao et al. (1998) [33]	51	Asia	C	A
Ucerler and Ikiz (2005) [35]	30	Asia	C	A
Ucerler et al. (2007) [36]	34	Asia	C	A
Wahee et al. (2010) [37]	60	Asia	C	F

[a] *C* Cadaveric, *U* Ultrasound

[b] *A* Adults, *F* Fetuses

and sex of the fetuses ($p = 0.545$). The prevalence of the variations was pooled in the meta-analysis displayed on forest plots. Results of the dissections are presented in Table 2.

SFN branching patterns concerning the deep fascia

Twenty-five studies reported data on the SFN branching at the deep fascia ($n = 1272$ lower limbs). In the overall analysis, Type 1 was the most common pattern (86.4%; 95% CI 84.5–88.2; $I^2 = 92.3\%$; $p < 0.0001$). Type 2 was the least common (13.6%; 95% CI 11.8–15.5; $I^2 = 92.3\%$; $p < 0.0001$). Table 3 shows the subgroup analysis for this variable. A statistically significant association was found between geographical subgroups and variations for the SFN branching patterns ($p < 0.001$), demonstrating unequal distribution among the geographical subgroups.

SFN branching patterns concerning the ankle joint level

Six studies reported data on the SFN branching at the ankle joint level ($n = 389$ lower limbs). In the overall analysis,

Table 2 Dissection results of the present cadaveric study

	SFN variations regarding the ankle joint				SFN variations regarding the deep fascia			
	Side		Sex		Side		Sex	
	Right (%)	Left (%)	Male (%)	Female (%)e	Right (%)	Left (%)	Male (%)	Female (%)
Type 1	6.7	10.0	10.8	5.8	40.0	43.3	44.2	39.2
Type 2	35.8	32.5	33.3	35.1	6.7	10.0	5.8	10.8
Type 3	2.5	4.2	2.5	4.2	–	–	–	–
Type 4	3.3	2.5	2.5	4.2	–	–	–	–
Type 5	0.8	1.7	0.8	0.8	–	–	–	–

Table 3 Subgroup analysis of SFN branching patterns in relation to the deep fascia. Data are presented as pooled prevalence (95% confidence interval)

Geographical locations	Type 1	Type 2
Asia	84.7 (81.7–87.6)	15.3 (12.4–18.3)
Europe	78.4 (73.5–83.2)	21.6 (16.8–24.5)
North America	91.3 (86.6–95.4)	8.7 (4.6–13.4)
South America	82.8 (76.5–88.6)	17.2 (11.4–13.5)
Oceania	99.6 (98.0–100)	0.4 (0.0–2)

Type 2 was the most common variation (61.0%; 95% CI 56.0–65.7; $I^2=49\%$; $p=0.08$), followed by Type 1 (21.4%; 95% CI 17.3–25.5; $I^2=0\%$; $p=0.43$) and Type 3 (9.4%; 95% CI 6.6–12.4, $I^2=0\%$; $p=0.47$). Type 4 (5.5%; 95% CI 3.3–7.8, $I^2=78\%$; $p<0.01$) and Type 5 (2.7%; 95% CI 1.2–4.4, $I^2=59\%$; $p=0.03$) were the least commons. Table 4 shows the subgroup analysis. No significant differences were found among the geographical subgroups ($p<0.212$).

Discussion

The present systematic review study aimed to assess the SFN anatomy. The existence and pooled prevalence of two SFN branching patterns in relation to the deep fascia and five branching patterns concerning the ankle joint level have been reported throughout this study. Knowing these anatomical variations have great importance to avoid iatrogenic injuries to this nerve in ankle and leg surgeries and for the proper performance of regional anesthesia on the leg and foot.

The SFN is the most commonly injured structure in ankle arthroscopy because of its high anatomical variability [3, 20, 39]. Considering the ankle joint level, Type 1 and Type 3 anatomies were more prevalent in Asian populations (26% and 12.4%, respectively), while Type 2 was more common in South American populations (69%). Type 4 was most prevalent in populations from Oceania (17.5%), and Type 5 was most common in populations from North America (10.2%). We found significant differences among the geographical groups. These data may show the need for caution when performing surgical procedures since the SFN anatomy may vary by geography.

Variations in SFN anatomy can lead to SFN entrapment syndrome, which may occur when the SFN is compressed by the deep fascia when piercing it to become subcutaneous in the distal leg [14, 18, 32]. The SFN anatomy influences the symptomatology and therapy of SFN entrapment. Subgroup analysis showed Type 1 was more prevalent in all geographical subgroups, with significant differences among all subgroups. These data may alert to the surgical precautions for patients from different geographical subgroups undergoing fascia release surgery.

Although SFN is still underused for nerve grafts [37], this is one of the best clinical and surgical uses of this nerve [18, 26]. SFN provides a lengthy graft and also has a relatively foreseeable course. Further, the SFN may be harvested without major problems for the donor because the lack of its sensory portion only affects the sensitivity of the dorsum of foot [26]. Knowing the different SFN branching types ensures better use of the nerve and may prevent injuries in the branches involved in the harvest of SFN [26]. Electroneuromyography tests may be used as non-invasive clinical assessment of possible SFN variations [11]. The preoperative use of these tests can avoid iatrogenic injuries to SFN.

Imaging examinations may be used to assess the SFN anatomy, and ultrasonography is particularly useful [6, 7]. However, some comorbidities, such as morbid obesity, arteriopathies, or heart failure may cause image obstruction by excess tissue or subcutaneous fluid. Knowing the SFN branching variations becomes more relevant in these cases. The principal use of this ultrasound-applied information is during SFN blocks. Patients with these comorbidities derive the greatest benefit from using regional anesthesia, which avoids the potential complications of general anesthesia. Clinical and surgical experience has shown the relevance of knowing the SFN location and branching to treat diseases, syndromes, or injuries [6].

The absence of detailed descriptions of the ethnicities of the primary study subjects limited the present study. This restricted us to a geographical subgroup analysis, which is not as important clinically or surgically as an ethnicity-based analysis. Moreover, detailed descriptions with regard to sex and side were not provided, which also limited our analyses.

Table 4 Subgroup analysis of SFN branching patterns in relation to the level of the ankle joint

Geographical location	Type 1	Type 2	Type 3	Type 4	Type 5
Asia	26 (19.2–33.4)	60 (52–67.8)	12.4 (7.6–18.3)	0.8 (0–3.2)	0.8 (0–3.4)
North America	16.1 (7.0–27.6)	61.3 (48.1–75)	6.2 (0.08–14.7)	6.2 (0.08–14.7)	10.2 (3–20.1)
South America	15.8 (10.2–23.4)	69 (60.6–77)	6.5 (2.7–11.6)	6.5 (2.7–11.6)	1.8 (0–4.8)
Oceania	23.8 (14.1–34.4)	46.7 (35.3–59)	8.9 (3–16.9)	17.5 (9.4–27.7)	3 (0–8.7)

Data are presented as pooled prevalence (95% confidence interval)

The present review found statistically significant differences in the distribution of nerve variations, which are important from a clinical and surgical viewpoint. Due to the possibility of unforeseen variations, the surgeon and anesthesiologist need to carefully analyze the SFN branching.

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Author contributions All the authors significantly contributed to the performance of this study.

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Data availability Not applicable.

Declarations

Competing interests The authors declare no competing interests.

Conflict of interest The authors declare no competing interests.

Ethical approval This study was approved by the Human Research Ethics Committee of the Federal University of Sergipe (no. 79260417.0.0000.5546).

Consent for publication Not applicable.

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