

Cynthia K. Shortell, MD, **SECTION EDITOR**

Systematic review and meta-analysis of the anatomic variants of the saphenofemoral junction



Roberto Cirocchi, MD,^a Brandon Michael Henry, MD,^b Massimo Rambotti, MD,^c Krzysztof A. Tomaszewski, MD, PhD,^b Massimo Cappelli, MD,^d Gianfranco Vettorello, MD,^e Alessandra Pistilli, MD,^f Vito D'Andrea, MD,^g Bruno Amato, MD,^h and Justus Randolph, MD,ⁱ *Perugia, Civitanova Marche, Florence, Udine, Rome, and Naples, Italy; Kraków, Poland; and Atlanta, Ga*

ABSTRACT

Background: The aim of this systematic review was to provide comprehensive data on the prevalence of variations of the saphenofemoral junction (SFJ) to prevent misidentification of the SFJ or the incomplete ligation of the tributaries of the great saphenous vein.

Methods: A systematic review was conducted using the PubMed, Embase, and Cochrane Library databases through September 14, 2017. To be included in the meta-analysis, a study had to report prevalence data on the morphology of the SFJ or the presence of venous tributaries.

Results: A total of 16 studies (7433 legs) were included. The majority of studies were performed during varicose vein surgery (74.14%), with fewer studies by means of computed tomography venography and cadaveric dissection. The pooled prevalence estimate (PPE) for a duplication of the SFJ with a bifid junction was 9.6% ($P = .001$). The PPE for a duplication of the SFJ with two separate junctions was 1.7%. The PPE for ectasia of the SFJ was 2.3% in type 1, 1.2% in type 2, and 1.7% in type 3. The distribution of the PPE for the number of venous SFJ tributaries was approximately normal with a slight right skew; a higher rate was observed in the group with four venous tributaries to the SFJ.

Conclusions: This analysis found high heterogeneity in the prevalence of SFJ anatomic variants and the number of venous SFJ tributaries. For this reason, it is highly recommended that a preoperative Doppler ultrasound assessment of the SFJ and great saphenous vein be performed. (*J Vasc Surg: Venous and Lym Dis* 2019;7:128-38.)

Keywords: Saphenofemoral junction; Great saphenous vein; Varicose veins

The great saphenous vein (GSV) is the longest superficial vein of the leg.¹ In the past, the GSV has been described by other terms, such as long saphenous vein and saphena magna.²

The trunk of the GSV forms the saphenous arch to join with the common femoral vein (CFV) at the saphenofemoral junction (SFJ) in the region of the femoral triangle.

This arch is highly variable, with numerous types of anatomic alterations. It also receives a variable number of tributaries that drain the abdominal wall and the perineal region. As such, the venous anatomy of this region is highly complex.³

Anatomic variants of the GSV may be responsible for surgical failures in varicose vein treatment⁴; an incomplete ligation of the tributaries of the SFJ may lead to permanent flow through the GSV arch and recurrence of varicose veins of the lower limbs.⁵ For this reason, it is important to perform a routine preoperative duplex ultrasound examination.⁶ Treatment strategies are still evolving and are also modified according to the economic needs in the treatment of varicose disease. Thus, an anatomic study should be a basic investigation offered in any choice of treatment.

According to common international anatomic textbooks, the venous tributaries of the GSV arch form a “venous star” composed of five venous tributaries (Supplementary Table I, online only), with a few sources describing only three venous tributaries.⁷⁻¹⁰ The venous tributaries of the SFJ can be divided into two groups, with the higher tributaries draining the lower abdomen and pelvis and the lower tributaries draining the leg. However, these classic textbooks infrequently describe the anatomic variants, and the

From the Department of Surgery and Biomedical Sciences,^a and Department of Surgery and Biomedical Sciences,^f University of Perugia, Perugia; the Department of Anatomy, Jagiellonian University Medical College, Kraków^b; the Unit of Surgery, Casa di Cura “Villa Pini,” Civitanova Marche^c; Private Centro Vena, Florence^d; the Department of General Surgery, General Hospital, Tolmezzo^e; the Department of Surgical Sciences, Sapienza University of Rome, Rome^g; the Department of Clinical Medicine and Surgery, University of Naples Federico II, Naples^h; and the Tift College of Education, Mercer University, Atlanta.ⁱ

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Correspondence: Brandon Michael Henry, MD, Department of Anatomy, Jagiellonian University Medical College, 12 Kopernika St, 31-034 Krakow, Poland (e-mail: bmhenry55@gmail.com).

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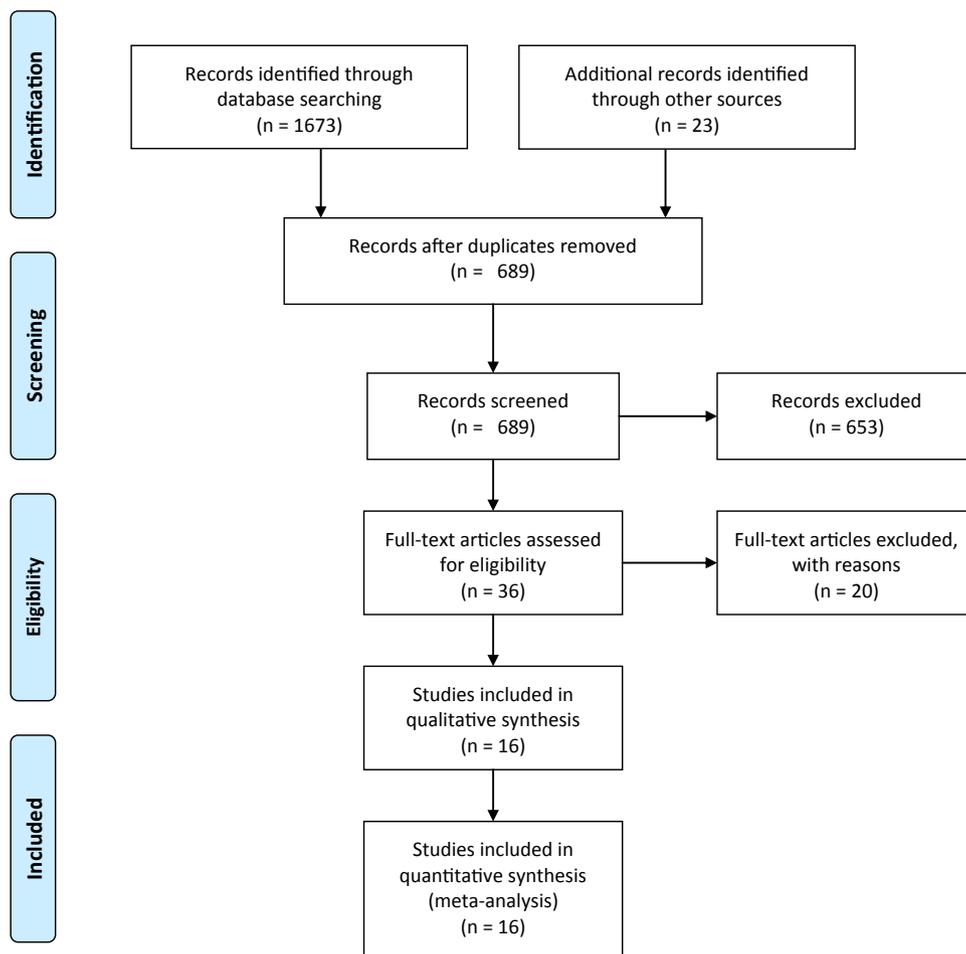


Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2009 flow diagram.

number of venous tributaries reported by various studies is significantly heterogeneous.

For proper planning of varicose vein treatment, numerous classifications of anatomic variants of the SFJ (Supplementary Table II, online only)¹¹⁻¹⁵ and its venous tributaries (Supplementary Table III, online only) have been proposed.¹⁶⁻¹⁹ However, the studies proposing these classifications were limited by their small sample sizes.

The hemodynamic interpretation of the normal and pathologic venous system considers the SFJ as a perforator, constituting a point of drainage, escape, and re-entry of the superficial venous system.²⁰

The frequent use of endovenous therapies (foam sclerotherapy, radiofrequency ablation, endovenous thermal ablation) has reduced the common importance given to the anatomy of the SFJ and its tributaries. Indeed, the identification of anatomic variations of the SFJ is not always necessary, as shown with the common treatment of GSV incompetence. The presence of anatomic variants of the SFJ is still a critical preoperative question in some particular scenarios; for these reasons, the preoperative duplex ultrasound evaluation of the SFJ is mandatory in these selected patients. In effect, the

preoperative duplex ultrasound identification of these anatomic variants of the SFJ is currently still needed only for prevention of the misidentification of the SFJ at crosssection during stripping of the GSV and at ligation-disconnection of the proximal GSV according to the Cure Conservatrice et Hémodynamique de l'Insuffisance Veineuse en Ambulatoire (CHIVA) method or the incomplete ligation of the tributaries of the GSV during crosssection and stripping of the GSV.

The aim of this systematic review and meta-analysis was to analyze and provide comprehensive data on the prevalence, anatomic characteristics, and variations of the SFJ.

METHODS

Study selection. A systematic review examining available data from studies assessing the anatomic variations of the SFJ and its venous tributaries was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses²¹ standards. A comprehensive literature search was conducted using the PubMed, Scopus, Web of Science, and Cochrane Library databases through September 14, 2017,

Table I. Studies included in the systematic review

Author	Year of publication	Country	Study design	Procedure for location of the SFJ and its venous tributaries	Time of enrolled participants
Kim et al	2017	Korea	POS	Computed tomography venography	NR
Souroullas et al	2017	United Kingdom	POS	During varicose vein surgery	2003-2005
Gerez et al	2014	Argentina	NR	During varicose vein surgery	NR
Tavlaşoğlu et al	2013	Turkey	NR	During varicose vein surgery	2011-2013
Hemmati et al	2012	Iran	NR	During varicose vein surgery	2007-2009
Siani et al	2012	Italy	ROS	During varicose vein surgery	2002-2012
Udhaya et al	2011	India	POS	Cadaveric dissection	NR
Ciucci et al	2010	Argentina	POS	Cadaveric dissection	NR
Mühlberger et al	2009	Austria	POS	Cadaveric dissection	2005-2006
Donnelly et al	2005	Ireland	POS	During varicose vein surgery	1995-2003
Janowski and Topol	2004	Poland	POS	During varicose vein surgery	NR
Sanchez et al	2001	Spain	NR	During varicose vein surgery	1996-2001
Chun et al	1992	Korea	POS	Cadaveric dissection	1989-1991
Morin et al	1970	France	POS	During varicose vein surgery	NR
				Cadaveric dissection	
Daseler and Anson	1946	United States	POS	Cadaveric dissection	NR
Glasser et al	1943	United States	POS	Cadaveric dissection	NR

NR, Not reported; POS, prospective observational study; ROS, retrospective observational study; SFJ, saphenofemoral junction.

employing the terms “saphenofemoral” and “junction.” No language or publication date restrictions were imposed.

Full-text papers were independently screened by two authors (R.C. and M.R.) for eligibility. When multiple articles were published from a single study group in which overlapping study periods were reported, only the most recent article was considered to avoid duplication of data. The PubMed function “related articles” was used to broaden each search, and the reference list of all potentially eligible studies was analyzed. To minimize retrieval bias, a manual search method inclusive of the Google Scholar database was performed. A final decision on eligibility was reached by consensus between the two screening authors.

Inclusion and exclusion criteria. To be included in the meta-analysis, a study had to satisfy the criterion of reporting prevalence data concerning the morphology of the SFJ or the presence of venous tributaries.

The following exclusion criteria were applied: case reports, editorials, conference abstracts, and studies reporting incomplete or irrelevant data.

A protocol for this meta-analysis was registered on PROSPERO: CRD42016051652 (<http://www.crd.york.ac.uk/prospero>).

Data extraction. A data extraction sheet based on the Cochrane Consumers and Communication Review Group’s data extraction template was developed.²² Two

authors (R.C. and M.R.) independently retrieved data of the included studies. A third author (J.R.) checked the extracted data. Disagreements were solved through discussion and, if necessary, by involving an independent fourth author (V.D.).

For each study, the following information (when available) was extracted and summarized: first author’s surname and year of publication, country of the hospital in which the study was performed, study design, number of patients, and number of legs evaluated.

Outcomes. The primary outcome of interest was anatomic variation of the SFJ. The alterations of the SFJ were subdivided according to the classification reported by Blanchemaison and Greney²³ in the *Atlas of Anatomy of the Superficial Veins of the Lower Limbs*, which is freely accessible on the Internet (<https://www.phlebologia.com>).

The following were considered secondary outcomes:

number of venous SFJ tributaries, including those joining the arch of the GSV and the CFV. This outcome was performed in accordance with the study by Donnelly et al.²⁴ number of venous tributaries to the GSV. This outcome was performed in accordance with the study of Souroullas et al,¹⁵ which reported a range of one to six venous tributaries to the SFJ.

number of venous tributaries to the CFV. This outcome was performed in accordance with the study of Souroullas et al,¹⁵ which reported a range of zero to three venous tributaries to the CFV.

Table II. Characteristics of included studies

Author	No. of enrolled participants	No. of legs analyzed	Female/male	Age, years	Disease at lower limbs	Extension of dissection of CFV
Kim et al	405	810	239/166	57 (median)	Varicose vein in 584 limbs	
Souroullas et al	172	172	110/62	47.2 (mean)	CEAP clinical class C2s or above SVI	1 cm proximal and distal to the SFJ
Gerez et al	113	142	63/50	46 (median)	Incontinence of SFJ valve	NR
Tavlaşoğlu et al	156	156	NR	21.64 (mean)	SVI	NR
Hemmati et al	228	228	82/146	45.03 (mean)	GSV reflux and SFV insufficiency	NR
Siani et al	NR	2275	NR	NR	SVI	NR
Udhaya et al	35	70	13/22	NR	None	
Ciucci et al	100	100	NR	NR	None	
Mühlberger et al	114	217	62/52	79.3	None	
Donnelly et al	NR	2086	NR	44.6 in women (mean) 45.4 in men (mean)	Primary varicose veins for SFV	2 cm proximal and distal to the SFJ
Janowski and Topol	NR	94	NR	NR	Chronic vein insufficiency	NR
Sanchez et al	121	121	NR	NR	Chronic vein insufficiency	NR
Chun et al	129	249	56/73	NR	None	
Morin et al	237	237	NR	NR	Primary varicose veins for SFV	NR
	13	26	NR	NR	None	
Daseler and Anson	NR	350	NR	NR	None	
Glasser et al	50	100	NR	NR	None	

CEAP, Clinical, Etiology, Anatomy, and Pathophysiology; CFV, common femoral vein; GSV, great saphenous vein; NR, not reported; SFJ, saphenofemoral junction; SFV, superficial femoral vein; SVI, superficial venous insufficiency.

Statistical methods. Binomial and multinomial pooled prevalence estimates (PPEs) and their 95% confidence intervals (CIs) were calculated using MetaXL software (version 5.0; EpiGear International, Sunrise Beach, Australia). Random-effects models were used for each analysis. Outcomes were synthesized only when there was more than one study and nonzero variance for that outcome. We followed the methods in the *Cochrane Handbook for Systematic Reviews of Interventions* in terms of investigating study heterogeneity.²⁵ As indicators of heterogeneity, the I^2 statistic, its 95% CIs, and significance levels of Cochrane Q were reported. Funnel plots were examined for outcomes with >10 cases. We conducted subgroup analyses for geographic region (Asia, Europe, North America, and South America) and type of exposition (cadaveric, surgical, or radiologic) for outcomes in which there were at least two studies per group. Variance components analyses were performed with SPSS 24.0 software (IBM Corp, Armonk, NY).

To examine the effect that removing any single study would have on the PPE, a leave-one-out sensitivity analysis was conducted for each outcome that had at least three studies.²⁶

RESULTS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for the systematic review is presented in Fig 1. The initial search yielded 1696 potentially relevant articles. After removal of duplicates and screening by titles and abstracts for relevance and assessment for eligibility, 653 more articles were excluded, leaving 36 studies for analysis of full text. Of these, 20 were excluded because the primary or secondary outcome of the study did not match that of this review (Supplementary Table IV, online only).²⁷⁻⁴⁶ Thus, a total of 16 articles were included in this systematic review and meta-analysis (Table I).^{13,15,16,18,24,47-57}

Table III. Anatomic variation at the saphenofemoral junction (SFJ)

Study	No. of legs studied	Duplication of SFJ			Ectasia of SFJ				
		Bifid junction	Two separate junctions	Insular duplication	First type of Blanchemaison	Second type of Blanchemaison	Third type of Blanchemaison	Plexiform SFJ	H-shaped SFJ
Souroullas, 2017	172	4 (2.3)	NR	NR	NR	NR	NR	NR	NR
Gerez, 2014	142	4 (2.8)	1 (0.7)	NR	4 (2.8)	2 (1.4)	1 (0.7)	NR	NR
Tavlaşoğlu, 2013	156	3 (1.9)	6 (3.8)	NR	NR	NR	NR	NR	NR
Siani, 2012	2275	35 (1.5)	NR	NR	NR	NR	NR	NR	NR
Udhaya, 2011	70	2 (2.8)	NR	NR	NR	NR	NR	NR	NR
Ciucci, 2010	100	22 (22)	NR	NR	NR	NR	NR	NR	NR
Donnelly, 2005	2086	379 (18.1)	NR	NR	NR	NR	NR	NR	NR
Janowski, 2004	94	4 (1.2)	NR	NR	NR	NR	NR	NR	NR
Sanchez, 2001	136	15 (11)	1 (0.7)	2 (1.5)	2 (1.5)	1 (0.7)	4 (1.5)	NR	2 (1.5)
Chun, 1992	325	125 (38.6)	NR	NR	NR	NR	NR	NR	NR
Morin, 1970	237	54 (22.8)	NR	NR	NR	NR	NR	NR	NR
		26	8 (30.8)	NR	NR	NR	NR	NR	NR
Classer, 1943	100	3 (3)	NR	NR	NR	NR	NR	NR	NR

NR, Not reported.
Values are reported as No. (%).

Characteristics of studies

In the 16 included studies, 7433 legs were examined. A majority of studies were performed during varicose vein surgery (5511 legs [74.1%]), whereas fewer studies were performed using three-dimensional computed tomography venography (810 legs [10.9%]) and cadaveric dissection (1112 legs [15.0%]). Only one study reported the registration of a study protocol.¹⁵

The majority of studies were performed in Europe (seven studies; 5228 legs [70.3%]), with fewer studies performed in Asia (five studies; 1513 legs [20.3%]), North America (two studies; 450 legs [6.0%]), and South America (two studies; 242 legs [3.2%]). No identified study was performed in Africa or Australia. All cadaveric studies were prospective studies. In the group of varicose vein surgery studies, only five articles (55.5%) reported the type of study

design: four prospective observational studies and one retrospective observational study. The single radiologic imaging study was retrospective (Table I).

Seven articles reported the length for which the participants were enrolled (between 3 and 17 years). The cadaveric studies were published between 1943 and 2011; studies performed on patients who underwent varicose vein surgery were published between 1970 and 2016 (Table I). Only seven studies reported the sex for a combined 1196 participants (625 female patients [52.2%] and 571 male patients [47.7%]) with a mean age range between 21.6 and 79.3 years (Table II). All participants who underwent surgery or computed tomography venography were affected by GVS reflux, whereas all participants who underwent cadaveric dissection had no lower limb disease reported. Only two studies reported

Table IV. Study-reported data on number of venous saphenofemoral junction (SFJ) tributaries

Study	No. of legs studied	No. of venous tributaries of SFJ							
		0	1	2	3	4	5	6	7
Kim, 2017	810	0	0	25	236	360	160	0	0
Hemmati, 2012	228	0	0	18	61	94	43	11	1
Chun, 1992	265	0	0	34	61	75	95	0	0
Daseler, 1946	350	0	0	144	154	52	0	0	0

Table V. Study-reported data on number of venous tributaries to the arch of the great saphenous vein (GSV)

Study	No. of legs studied	No. of venous tributaries to arch of GSV							
		0	1	2	3	4	5	6	7
Souroullas, 2017	172	0	3	20	62	60	21	6	0
Mühlberger, 2009	217	1	4	16	57	99	40	0	0
Janowski, 2004	94	0	4	14	45	23	5	3	0
Chun, 1992	265	0	0	17	49	52	0	0	0
Daseler, 1946	350	0	0	144	154	52	0	0	0

the length of the dissection proximal and distal to the SFJ: 1 cm in the study of Souroullas et al,¹⁵ and 2 cm in the study of Donnelly et al.²⁴ The definition of SFJ alteration was reported in five studies for duplication of the SFJ (bifid junction) and in two studies for ectasia of the SFJ, plexiform SFJ, and H-shaped SFJ (Supplementary Table V, online only). The study-level data on anatomic variations at the SFJ are reported in Table III. Study-level data on the number of venous tributaries of the SFJ and venous tributaries of the GSV are reported in Tables IV and V, respectively. Study-level data on the number of venous tributaries to the CFV are reported in Table VI. In this review, we considered all three types of ectasia of the SFJ as reported by Blanchemaison and Greney.²³ The ectasia is not distinguished from venous aneurysms because no consensus is reported on the criteria for the designation of venous aneurysms. Pascarella et al⁵⁸ reported the criterion as 1½ times the size of the contiguous vein, whereas Gabrielli et al⁵⁹ have included thrice the size of the normal vein or twice the size of the contiguous vein.

Statistical analysis

Duplication of the SFJ (bifid junction). Twelve studies reported the prevalence of duplication of the SFJ (bifid junction) in 5919 legs (Fig 2; Table III). The PPE for a bifid junction was 9.6% (95% CI, 3.8%-17.6%; $I^2 = 98.36$ [95% CI, 97.9-98.7]; $P = .001$; Fig 3). A leave-one-out sensitivity analysis resulted in PPEs between 7.9% and 10.8%. As the forest plot shows, there was significant heterogeneity among the studies. The heterogeneous grouping of studies was also reflected in an atypical funnel plot. A variance components analysis indicated that the type of study was the factor that accounted for the greatest amount of variance in the model, as it accounted for 23.0% of the variance in the PPE of bifid junctions. In subgroup analysis, no significant differences were observed for

Table VI. Study-reported data on the number of venous tributaries to the common femoral vein (CFV)

Study	No. of legs studied	No. of venous tributaries to CFV			
		0	1	2	3
Souroullas, 2017	172	102	66	3	1
Chun, 1992	265	189	61	15	0

geographic region and type of study (Supplementary Figs 1 and 2, online only).

Duplication of the SFJ (two separate junctions). Three studies reported the prevalence of separate junctions (Fig 4) in 434 legs (Table III).^{13,47,48} The PPE was 1.7% (95% CI, 0.3%-4.0%; $I^2 = 52.6$ [95% CI, 0.0-86.4]; $P = .12$). No significant findings were observed in the sensitivity analysis.

Ectasia of the SFJ. Two studies reported on the prevalence of a type 1 (Fig 5, A), type 2 (Fig 5, B), and type 3 ectasia (Fig 5, C) of the SFJ for 278 legs (Table III).¹⁵⁻⁴⁷ The PPE was 2.3% (95% CI, 0.7%-4.4%) in type 1, 1.2% (95% CI, 0.2%-2.9%) in type 2, and 1.7% (95% CI, 0.1%-4.5%) in type 3 (Supplementary Table VI, online only). The limited number of studies prevented the calculation of I^2 .

Number of venous SFJ tributaries. Four studies reported the prevalence of the number of venous SFJ tributaries in 1653 legs (Table IV).^{16,18,46,49} The distribution of the PPE for the number of tributaries was approximately normal with a slight right skew (Fig 6); the highest rate was reported for four venous tributaries to the SFJ (35.7%; 95% CI, 9.8%-55.7%; Supplementary Table VII, online only). No remarkable findings were observed from the sensitivity analysis. Significant heterogeneity was observed among the studies ($I^2 = 98.9$ [95% CI, 98.3-99.3]; $P < .001$).

Number of venous tributaries to the arch of the GSV. In data pooled from five studies with 1098 legs (Table V), the highest multinomial PPE rate was found for three venous tributaries to the arch of the GSV (41.4%; 95% CI, 16.6%-52.7%). A subgroups analysis was also conducted on the basis of the type of surgical exposition; the PPEs were approximately normally distributed (Supplementary Table VIII, online only). A sensitivity analysis showed no meaningful differences despite the heterogeneity of the data.

Number of venous tributaries to the CFV. In data obtained from two studies and 437 legs (Table VI), the highest multinomial PPE was reported in the group with no venous tributaries to the CFV (Supplementary Table IX, online only). Significant heterogeneity was observed between the studies ($I^2 = 91.4$; 95% CI, 69.9-97.6; $P < .001$).

DISCUSSION

Knowledge of the anatomy of the SFJ and the anatomic variants of its confluent veins is useful and

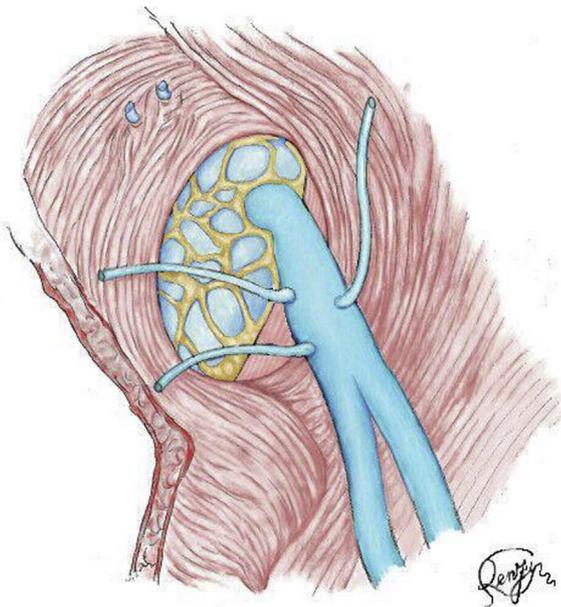


Fig 2. Duplication of the saphenofemoral junction (SFJ; bifid junction).

topic of interest, with different types of populations analyzed and multiple types of investigative modalities employed (Table I). The results of this meta-analysis significantly differ from the current descriptions reported in the majority of classic anatomic or surgical textbooks.

Most of the included studies reported only the prevalence rate of SFJ duplication; a few authors described ectasia of the SFJ, and only Sanchez¹³ included two cases with H-shaped SFJ. No study reported a plexiform-type SFJ. Furthermore, also in contradiction to the majority of anatomic texts, we found significantly heterogeneous results with respect to the number of tributaries to the SFJ.

In this meta-analysis, the anatomy of the SFJ was highly variable. A bifid SFJ, a pitfall variant for surgeons, was found to be present in 9.6% of legs with a wide 95% CI (3.8%-17.6%; Fig 3). Blanchemaison and Greney²³ reported that during a saphenectomy, this variant “constitutes a real trap when the duplication is situated outside the surgeon’s field of vision.” In such a case, if it is not identified, the largest GSV can be the stripper, with a residual hypoplastic venous trunk being a potential cause of varicose recurrence. Furthermore, as Genovese¹² suggested, it is difficult to distinguish a double GSV from accessory saphenous veins. Differently, the second type of duplication junction is easy to treat during GSV crosssection and was a rare event (1.7%). The first type of SFJ ectasia was the most common type of GSV ectasia (2.3% vs 1.2% in type 2 and 1.7% in type 3; Supplementary Table VI, online only). Surgical treatment of the first type of SFJ ectasia is simple, as the position of the ectasia is not near the CFV and thus an uncomplicated SFJ crosssection is performed. The second type of SFJ ectasia, however, is a surgical problem. In this case, the SFJ is surrounded by the ectasia, and thus only resection of the SFJ with CFV reconstruction can be performed. The H-shaped SFJ is

necessary, not only for the purpose of performing a complete and correct resective procedure in the case of traditional surgical treatment of the varicose veins (stripping of the GSV with ligation of the SFJ and its branches) but also for more modern therapeutic strategies, such as thermal ablation (laser or radiofrequency) of the large saphenous vein, when reflux. A detailed understanding of the complex venous anatomy is also essential in the proper execution of excision of saphenous segments in the groin, for the needs of arterial vascular surgery, and in cardiac or organ transplant surgery.

In our systematic review and meta-analysis, the literature search produced a wide variety of studies on the

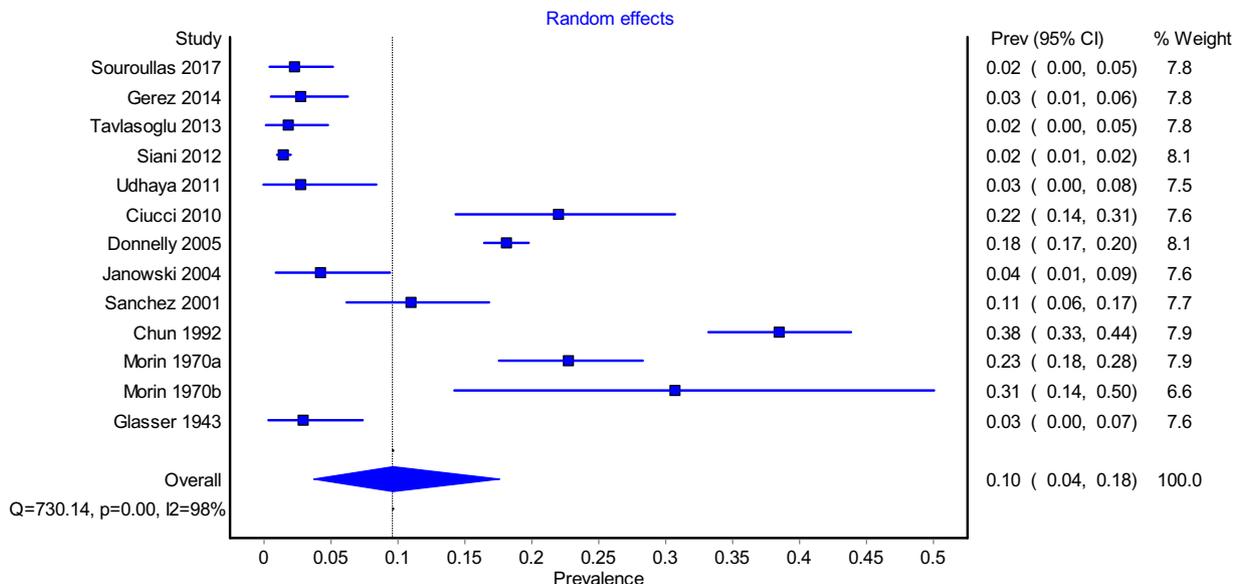


Fig 3. Forest plot of bifid junction (duplication of the saphenofemoral junction [SFJ]).

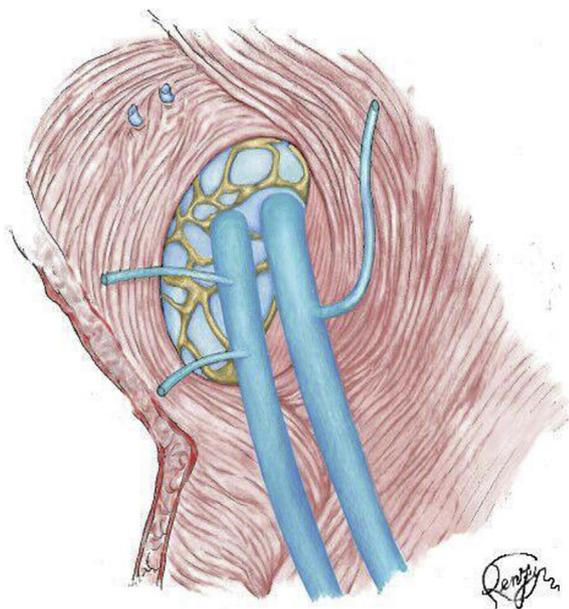


Fig 4. Duplication of the saphenofemoral junction (SFJ; two separate junctions).

a surgical pitfall, as a surgeon can confuse the GSV with the CFV. Studies on the incidence and characteristics of the duplication of the SFJ should be considered important for the purposes and indications of different procedures for the treatment of varicose veins of the lower limbs. Knowing their incidence and how the duplications of the SFJ occur could in fact direct the choice of treatment (endovascular or CHIVA or ablative of the saphenous vein). In particular, laser or radiofrequency endovascular treatment, in the event of preoperative or intraoperative misleading SFJ duplications, could be

burdened by greater complications of thermal lesions on the walls of the femoral venous system in the groin, when the probe is inadvertently positioned in their proximity, considering that the probe is positioned in a “thermal safety zone” in relation to the identification of a single junctional zone. Similarly, in case of the CHIVA technique, especially in obese patients, the lack of attention to and detection of duplication of the SFJ would result in early failures of the procedure and possible need for inguinal reinterventions, with the risks and difficulties in operating on previously scarred areas.

The highly variable number of venous SFJ tributaries as observed in this study presents further difficulties for surgeons. Knowledge of the number and exact localization of venous tributaries is important for reducing the risk of intraoperative technical errors. Following SFJ cross-section, remaining unidentified venous tributaries can be the source for continued venous flow and recurrent reflux.⁴ A complete venous star (five venous tributaries in the arc of the GSV), as it is described in many textbooks (Supplementary Table I, online only), was present in only 5.9% (Supplementary Table VIII, online only). A higher number of venous tributaries was reported in the analysis of venous SFJ tributaries; in these examinations, the classic venous star was reported in 15% (Supplementary Table VII, online only). In this analysis, three was the most common number of venous tributaries in the arch of the GSV (41.4%; Supplementary Table VIII, online only), and four was the most common number of venous tributaries in the SFJ (35.7%; Supplementary Table VII, online only).

In our analysis, in about one-third of cases, the GSV (66%) was not associated with venous tributaries at the level of the CFV (Supplementary Table IX, online only).

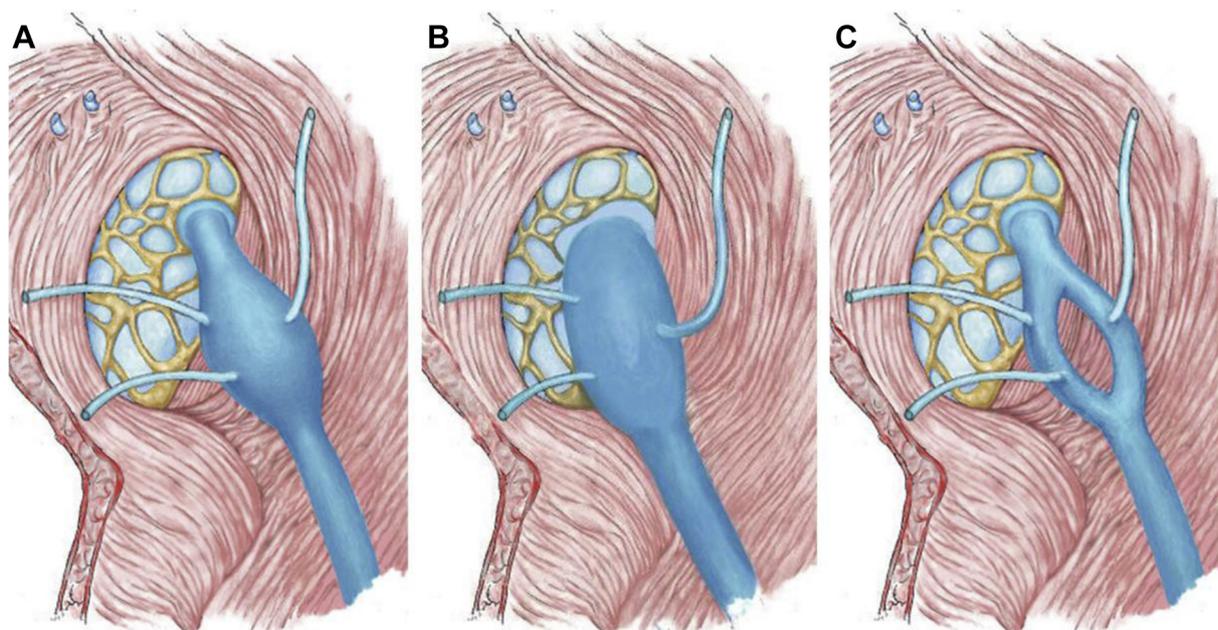


Fig 5. Ectasia of the saphenofemoral junction (SFJ), type 1 (A), type 2 (B), and type 3 (C).

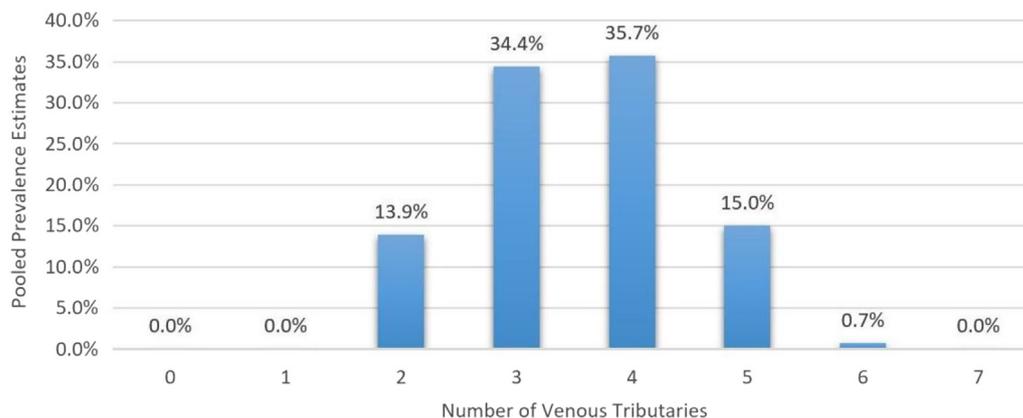


Fig 6. Distribution of the pooled prevalence estimates (PPEs) for the number of venous saphenofemoral junction (SFJ) tributaries.

However, it is not currently possible to correlate anatomic data with hemodynamic data regarding the distribution of the upper tributaries of the SFJ and their direction of flow. The flow direction of these venous tributaries is significant as they drain from the lower abdominal venous network.⁶⁰

There is still debate about the precise role of preoperative ultrasound examinations of the groin for assessing the anatomy of the SFJ and its variants. This is particularly the case if the examiner is not sufficiently prepared for the identification of possible venous anatomic variants and their potential implications in the results of surgical treatment of varices, such as increased risk of recurrence.⁶¹

The presence of a significant number of anatomic variants of the SFJ induces some authors to consider this anatomic area a "perforating vein" in the groin.⁶² The perforating veins of the lower limb show a large variability in their configuration, the same as occurs in the groin, where the large saphenous vein assumes a narrow structural identity (between the trunk of the saphenous vein and its joining tract in the femoral vein) when it undergoes a secondary dilation because of venous reflux and insufficiency of the femoral and the saphenous valves at the ostium.

It is unclear to what degree the anatomic variations examined here are an artifact of the method of clinical identification or individual anatomic variation. It would be useful for future research to delve more deeply into this potential source of heterogeneity. This meta-analysis was limited by the high heterogeneity among studies as well as by the limited data available for some analyses. Furthermore, cadaveric studies (generally conducted on a population not specifically affected by saphenous venous insufficiency during their life) may differ from the findings reported during surgery for saphenous insufficiency. This is mainly due to poor dilation, in healthy patients, of some venous junctional and truncal districts that could be considered, on the

contrary, anatomically anomalous venous districts in surgical patients based on their significant dilation. Future studies should examine this anatomic region in African and Oceanian populations as well as look to correlate anatomic and hemodynamic data.

CONCLUSIONS

This analysis found high heterogeneity in the prevalence of the SFJ anatomic variants and the number of venous SFJ tributaries. These results suggest the need to improve preoperative and intraoperative strategies for reducing risk of the misidentification of the SFJ at crosssection during stripping of the GSV and at ligation-disconnection of the proximal GSV according to the CHIVA method or the incomplete ligation of the tributaries of the GSV during crosssection and stripping of the GSV. Because of the significantly variable venous anatomy, it is highly recommended to perform a preoperative Doppler ultrasound assessment of the SFJ and GSV and a meticulous dissection of the SFJ during surgery.

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AUTHOR CONTRIBUTIONS

Conception and design: RC, MR, MC, JR
 Analysis and interpretation: RC, BH, MC, JR
 Data collection: KT, GV, AP, VD, BA
 Writing the article: RC, MR, BA, JR
 Critical revision of the article: BH, KT, MC, GV, AP, VD
 Final approval of the article: RC, BH, MR, KT, MC, GV, AP, VD, BA, JR
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 BM and JR contributed equally to this article and share co-first authorship.

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Additional material for this article may be found online at www.jvsvenous.org.

Supplementary Table I (online only). Number and type of venous tributaries of the great saphenous vein (GSV) reported in international academic textbooks

Author and year of publication	Textbook	No. of venous tributaries	Type of venous tributaries
Delaney, 2014	<i>Netter's Surgical Anatomy and Approaches</i>	5	Superficial circumflex iliac Superficial epigastric External pudendal Medial and lateral accessory saphenous
Moore et al, 2014	<i>Clinically Oriented Anatomy</i>	3	Superficial circumflex iliac Superficial epigastric External pudendal
Tank, 2013	<i>Grant's Dissector</i>	3	Superficial circumflex iliac Superficial epigastric External pudendal
Snell, 2006	<i>Clinical Anatomy by Systems</i>	3	Superficial circumflex iliac Superficial epigastric External pudendal

Supplementary Table II (online only). Description of the anatomic variants of the saphenofemoral junction (SFJ)

Duplication of SFJ			
	I	II	III
Blanchemaison, 1997	Duplication of the arch of the long saphenous vein is so rare that it is only mentioned in a few publications concerning anatomical variants of the saphenofemoral junction. Two elements differentiate this variant from the classical configuration of an accessory saphenous vein associated with the main long saphenous trunk: —the two long saphenous veins have the same caliber and drain a common cutaneous territory; —they both lie in the same plane, parallel to the skin and run along the muscular aponeurosis. The duplicated saphenous veins therefore differ from accessory saphenous veins which have a smaller caliber and, more importantly, ensure the drainage of different cutaneous territories.		
	A common junction above the duplication	Two separate junctions. The two long saphenous veins enter the femoral vein separately and each one receives its own tributaries.	A common junction and an insular duplication
Genovese, 2002	It is formed in the oval fossa by the union of two double long saphenous veins which drain a common region; they have, moreover, the same diameter and have the same histologic characteristic of propulsive veins.	It is formed by a double independent saphenous-femoral junction of the two just mentioned saphenous veins with correspondent tributaries of the cross.	
Sanchez, 2001	<i>Desdoblamiento subyacente de la VSI</i>	<i>Cayado en "cañón de escopeta" (duplicación verdadera de la VSI)</i>	<i>Defecto insular de la VSI</i>
Williams, 2013	A double saphenous vein, which normally receives large anterolateral thigh veins and posteromedial thigh veins		
Souroullas, 2017	In the true bifid system, the two GSVs lie within the saphenous fascia in the same plane parallel to the skin. They are of the same caliber and drain a common cutaneous area. A common reporting error is that of anterior accessory saphenous vein, which drains a different territory to the GSV, being falsely identified as a second GSV		
Ectasia of the SFJ			
	I	II	III
Blanchemaison, 1997	The position of the ectasia allows resection of the saphenofemoral junction associated with ligation as close as possible to the femoral vein.	The saphenofemoral junction is surrounded by the ectasia, only resection of the saphenofemoral junction with femoral arterioplasty can be performed.	The ectasia no longer involves the saphenofemoral junction, but the underlying saphenous trunk.
Sanchez, 2001	<i>Ectasia en inmediata proximidad de la unión safenofemoral, sin involucrarla</i>	<i>La ectasia afecta a la unión safenofemoral</i>	<i>La ectasia afecta al tronco de la vena safena interna lejos de la unión Safenofemoral</i>
Plexiform junction			
Blanchemaison, 1997	It consists of well-defined venous networks in which each vessel is smooth and regular with a diameter between 1 and 3 mm.		
Genovese, 2002	It is formed by a frayed saphenous trunk divided in smaller trunks after muscular fascia perforation. These smaller trunks may reunite in one cross or may have more independent crosses		
Sanchez, 2001	<i>Unión safenofemoral en "delta de río" (cavernoma inguinal)</i>		
H-shaped junction			
Blanchemaison, 1997	This is a particular case of association of an accessory saphenous vein with the main saphenous trunk. The surgeon may then be faced with two situations when looking for the arch of the saphenous vein. In the first case, he identifies a "first arch" which simulates the arch of the long saphenous vein, particularly by the presence of one or two tributaries and the fact that it drains into a larger underlying vein, tending to suggest the femoral vein. The second variant creates a real H appearance. An accessory saphenous vein drains into the femoral vein away from and below the arch of the long saphenous vein. The accessory saphenous vein is connected to the long saphenous vein by a venous bridge forming the transverse bar of the H.		
Genovese, 2002	It is formed by the flow of double saphenous vein into the terminal part of saphenic arch, just before saphenous-femoral junction.		
Sanchez, 2001	<i>Cayado en "H"</i>		

GSV, Great saphenous vein.

Supplementary Table III (online only). Classification of types of great saphenous vein (GSV) tributary drainage

	Types of GSV tributary drainage
Janowski, 2004	Five variations of SFJ
Frullini, 1994	Five variations of SFJ
Chun, 1992	Twenty-eight types of SFJ
Bassi, 1962	Eight variations of SFJ
<i>SFJ</i> , Saphenofemoral junction.	

Supplementary Table IV (online only). Reason for exclusion of the studies

Author and year of publication	Principal outcomes reported from the excluded studies
Kim, 2017	The authors reported the rare anatomic variation of the GSV crossing posterior to the common femoral artery.
Gupta, 2016	The authors reported the distance of the SFJ from palpable anatomy.
Orsini, 2001	The authors reported the distance of the SFJ from palpable anatomy.
Nakhate, 2014	The authors reported the duplication of the GSV, but they do not describe the presence of an alteration of the SFJ.
Mirjalili, 2014	The authors reported the distance of the SFJ from palpable anatomy.
Rohini, 2013 ^a	The authors reported the duplication of the GSV, but they do not describe the presence of an alteration of the SFJ.
Igari, 2013	The authors do not report the prevalence of duplication of the GSV.
Kockaert, 2012	The authors reported the duplication of the GSV, but they do not describe the presence of an alteration of the SFJ.
Uribe, 2010	The authors reported the venous anatomy of the lower limb and do not report the alterations of the SFJ.
Udhaya, 2011	The authors reported the venous anatomy of the lower limb and do not report the alterations of the SFJ.
Kurkcuoglu, 2008	The authors reported the venous anatomy of the lower limb and do not report the alterations of the SFJ.
Caggiati, 2014	The authors reported the international nomenclature of the veins of the lower limb.
Garner, 2003	The authors reported the prevalence of the lateral accessory saphenous vein.
Cooper, 2003	The authors reported the incompetence in primary varicose veins.
Lefebvre-Vilardobo, 1991	The authors reported the distance of the SFJ from palpable anatomy.
Shah, 1986	The authors reported the duplication of the GSV, but they do not describe the presence of an alteration of the SFJ.
Furderer, 1986	The authors reported a narrative review on anatomic alterations of the SFJ.
Thomson, 1979	The authors reported the venous anatomy of the lower limb and do not report the alterations of the SFJ.
Sherman, 1949	The authors reported the venous anatomy of the lower limb and do not report the alterations of the SFJ.
Kosinski, 1926	The authors reported the venous anatomy of lower limb and do not report the alterations of the SFJ.

GSV, Great saphenous vein; SFJ, saphenofemoral junction.
^aRohini M, Pooja J. Duplication of great saphenous vein. Anatomical description and its clinical implications. Int J Biol Med Res 2013;4: 3372-4.

Supplementary Table V (online only). Reported definition of anatomic variation at the saphenofemoral junction (SFJ)

Study	Duplication of SFJ			Ectasia of SFJ			Plexiform SFJ	H-shaped SFJ
	Bifid junction	Two separate junctions	Insular duplication	First type	Second type	Third type		
Souroullas, 2017	X							
Gerez, 2014	X	X	X	X	X	X	X	X
Tavlaşoğlu, 2013	No	No						
Siani, 2012	No							
Udhaya, 2011	No							
Donnelly, 2005	X							
Janowski, 2004	No							
Sanchez, 2001	X	X	X	X	X	X	X	X
Chun, 1992	No							
Morin, 1970	X							
Glasser, 1943	No							

Supplementary Table VI (online only). Prevalence of type 1, type 2, and type 3 ectasia of the saphenofemoral junction (SFJ)

Ectasia type	PPE (95% CI)	I^2
1	2.3% (0.7%-4.4%)	0.0
2	1.2% (0.2%-2.9%)	0.0
3	1.7% (0.1%-4.5%)	45.1

CI, Confidence interval; PPE, pooled prevalence estimate. The *P* value for Cochran *Q* was $>.05$ for all rows. There were too few studies to compute the 95% CIs of I^2 . There were two studies with 278 legs for this outcome.

Supplementary Table VII (online only). Multinomial pooled prevalence estimates (PPEs) of the number of venous saphenofemoral junction (SFJ) tributaries

No. of venous tributaries	PPE, % (95% CI)
0	0.1 ^a (0.0-4.8)
1	0.1 ^a (0.0-4.8)
2	13.9 (0.0-3.3)
3	34.4 (9.1-54.6)
4	35.7 (9.8-55.7)
5	15.0 (3.0-34.6)
6	0.7 (0.0-7.5)
7	0.2 (0.0-5.4)

CI, Confidence interval.

$I^2 = 98.9$ (95% CI, 98.3-99.3); Cochran *Q* = 272.19; *P* < .001; four studies, 1653 legs.

^aIn the original data set, there were no legs with no tributaries or one tributary. The data presented in the table are statistical estimates.

Supplementary Table VIII (online only). Multinomial pooled prevalence estimates (PPEs) of the number of venous tributaries to the arch of the great saphenous vein (GSV)

No. of venous tributaries	PPE, % (95% CI)		
	All studies	Cadaveric studies	Surgical studies
0	0.3 (0.0-3.9)	0.3 (0.0-8.1)	0.2 (0.0-1.9)
1	1.5 (0.0-7.3)	0.6 (0.0-9.5)	2.5 (0.0-7.8)
2	17.0 (2.8-29.9)	2.7 (0.0-41.7)	13.0 (5.9-21.8)
3	41.4 (16.6-52.7)	38.7 (0.0-41.7)	41.9 (30.0-53.1)
4	32.8 (11.2-45.1)	33.5 (2.2-54.7)	30.3 (19.7-41.2)
5	5.9 (0.00-14.5)	3.9 (0.0-17.4)	8.7 (2.9-16.4)
6	1.1 (0.0-6.3)	0.1 (0.0-7.1)	3.1 (1.0-8.8)
7	0.2 ^a (0.0-3.4)	0.1 (0.0-7.1)	0.2 (0.00-1.9)

CI, Confidence interval.

All studies: $I^2 = 97.4$ (95% CI, 95.8-98.4); Cochran $Q = 155.07$; $P < .01$; five studies, 1098 legs.

Cadaveric exposition studies: $I^2 = 98.7$ (95% CI, 97.7-99.2); Cochran $Q = 149.39$; $P < .001$; three studies, 836 legs.

Surgical studies: $I^2 = 71.3$ (95% CI, 0.0-93.55); Cochran $Q = 3.84$; $P = .06$; two studies, 266 legs.

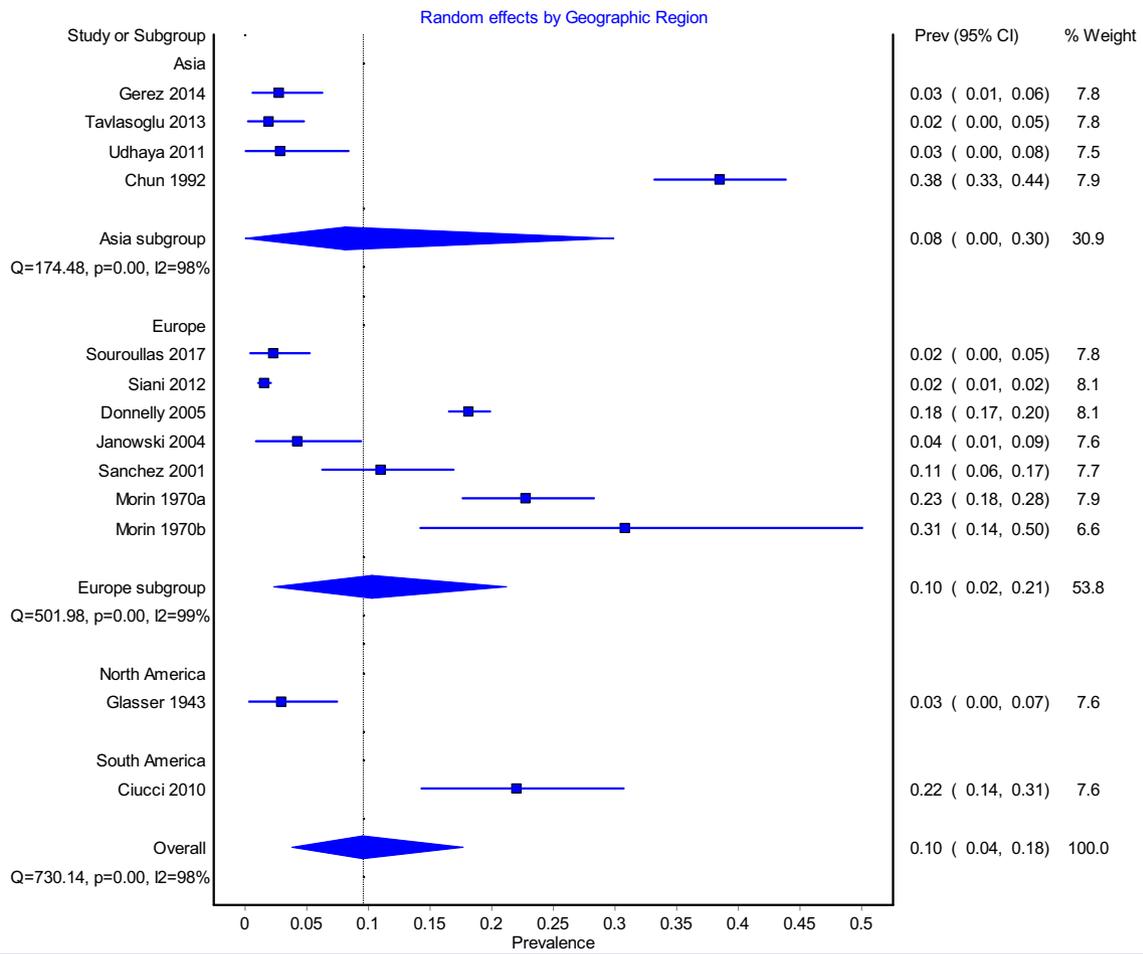
^aIn the original data set, there were no legs with seven tributaries. The data reported in the table are statistical estimates.

Supplementary Table IX (online only). Multinomial pooled prevalence estimates (PPEs) of the number of venous tributaries to the common femoral vein (CFV)

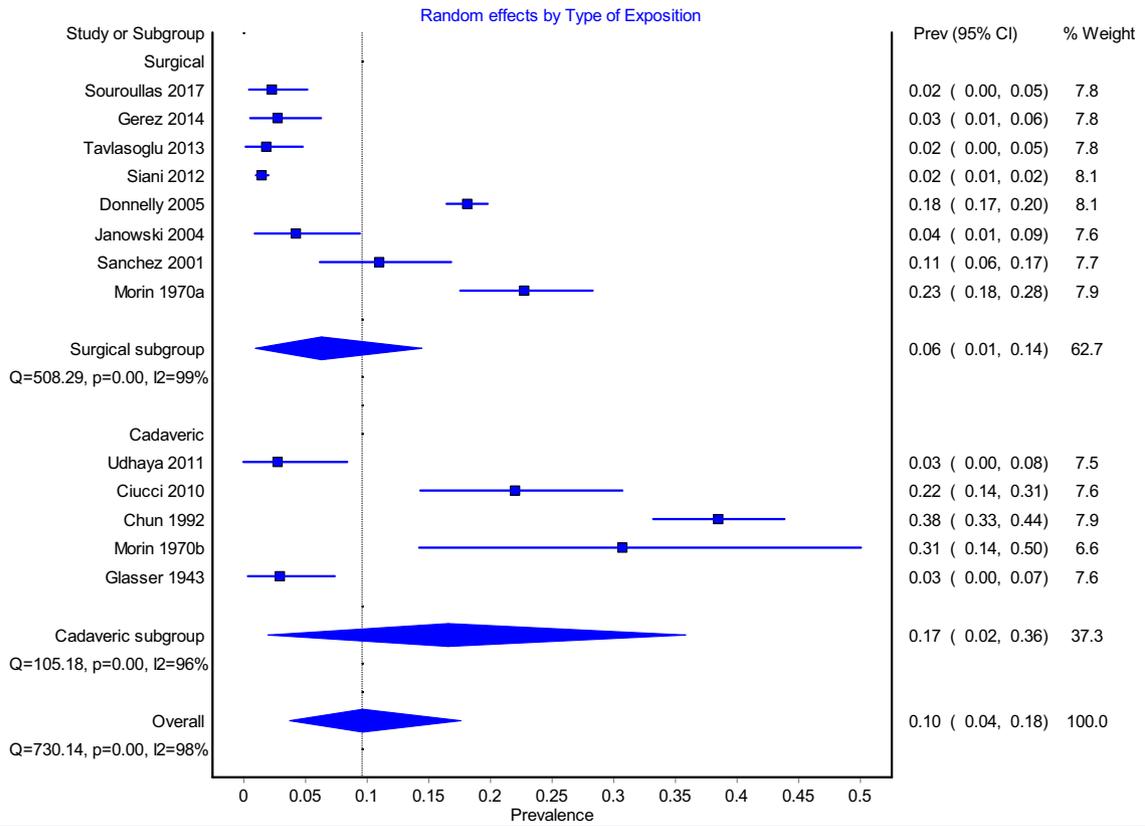
No. of venous tributaries	PPE, % (95%CI)
0	66.0 (49.3-80.8)
1	29.9 (15.7-46.1)
2	3.7 (0.0-11.2)
3	0.4 (0.0-3.8)

CI, Confidence interval.

All studies: $I^2 = 91.4$ (95% CI, 69.9-97.6); Cochran $Q = 11.66$; $P < .001$; two studies, 437 legs.



Supplementary Fig 1 (online only). Forest plot of pooled prevalence estimates (PPEs) for bifid junctions by geographic region.



Supplementary Fig 2 (online only). Forest plot of pooled prevalence estimates (PPEs) for bifid junctions by type of exposition.