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Three-Dimensional Evaluation of the Anatomic Variations of the Femoral Vein and Popliteal Vein in Relation to the Accompanying Artery by Using CT Venography

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Objective: We wanted to describe the three-dimensional (3D) anatomic variations of the femoral vein (FV) and popliteal vein (PV) in relation to the accompanying artery using CT venography.

Materials and Methods: We performed a retrospective review of 445 bilateral (890 limbs) lower limb CT venograms. After the 3D relationship between the FV and PV and accompanying artery was analyzed, the presence or absence of variation was determined and the observed variations were classified. In each patient, the extent and location of the variations and the location of the adductor hiatus were recorded to investigate the regional frequency of the variations.

Results: There were four distinct categories of variations: agenesis (3 limbs, 0.3%), multiplication (isolated in the FV: 190 limbs, 21%; isolated in the PV: 14 limbs, 2%; and in both the FV and PV: 51 limbs, 6%), anatomical course variation (75 limbs, 8%) and high union of the tibial veins (737 limbs, 83%). The course variations included medial malposition (60 limbs, 7%), anterior rotation (11 limbs, 1%) and posterior rotation (4 limbs, 0.4%). Mapping the individual variations revealed regional differences in the pattern and frequency of the variations.

Conclusion: CT venography helps to confirm a high incidence of variations in the lower limb venous anatomy and it also revealed various positional venous anomalies in relation to the respective artery.

Index terms: *Veins, anatomy; Veins, lower extremities; Veins, computed tomography; Duplication; Femoral vein; Popliteal vein*

INTRODUCTION

Knowledge of the venous anatomy and its variations is essential to accurately interpret the CT images and ultrasound examinations of the lower extremities. Knowledge of the diverse femoral and popliteal vein variations may be helpful for planning interventional procedures. Variations in the anatomy of the lower extremity venous system have been studied with the use of cadavers, venography and duplex ultrasonography (US), and these studies have shown different results depending on the study population and the modalities used (1–9). Quinlan et al. (8) recently reviewed 404 bilateral lower limb venograms that were free of thrombus and they analyzed the incidence, location and length of duplicated vessels. However, conventional venography may not necessarily be the most appropriate technique for assessing the detailed anatomy as it depends on adequate filling of all vessels, which is often not possible

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due to technical issues, and this leads to the assumption that the vessels are not present when they do not fill with contrast material (8). In addition, conventional venography is basically two-dimensional projection imaging without opacification of the arteries. Therefore, it is impossible to demonstrate the anatomical course and the relationship of the veins with the accompanying artery and as a result, to demonstrate the related variations.

The recent advent of multidetector CT (MDCT) has allowed sufficient high spatial resolution to show small extremity veins of less than 2 mm (10, 11). Furthermore, CT has enabled us to evaluate not only the presence of variant veins, but also their relationship to the accompanying artery or adjacent structures (12). Thus, in the era of MDCT, it is necessary to revisit and analyze the anatomy of the lower extremity venous system. As there have been no studies that have focused on the incidence and type of the lower limb venous system variations using CT venography, the purpose of our study was to describe the three-dimensional (3D) anatomy and variations of the femoral vein (FV) and the popliteal vein (PV) in relation to the accompanying artery by using CT venography in a large population that is free of thrombus.

MATERIALS AND METHODS

This retrospective study was approved by our Institutional Review Board and the requirement for informed consent was waived.

Patients

Between January 2002 and December 2003, a total of 634 patients underwent lower extremity CT venography for the assessment of varicose veins as a work-up for leg edema or for the preoperative evaluation of a fibular bone flap. During a retrospective review of the CT venography images, 189 patients were excluded for one of the following reasons: (a) a past history of lower extremity vascular surgery or endovascular treatment (n = 164), (b) deep vein thrombosis (DVT) (n = 23), (c) non-diagnostic venous opacification (n = 23), (d) a poor positional stature such as knee flexion (n = 6), and (e) congenital vascular malformation (n = 3). Finally, 445 patients (M:F = 225:220; mean age, 54 years; age range, 12–83 years) were enrolled in the study.

Multidetector CT Venography Technique

All the CT examinations were performed using a 4-row MDCT scanner (MX8000; Marconi Medical Systems, Cleveland, OH) or an 8-row MDCT scanner (LightSpeed Ultra; GE Medical Systems, Milwaukee, WI). The patients were placed in the supine position with the feet positioned to enter the gantry first. The extremities were positioned with the knee and ankle joints in the neutral positions. An apparatus supporting an ankle and buttock was used to provide leg elevation and avoid compression of the veins and muscles of the posterior thigh and calf. After obtaining an initial scout image (tube voltage: 100 kVp, tube current: 50 mAs), the scanning ranges were planned on an individual basis from the third lumbar vertebra to the level of the foot. An 18- or 20-gauge catheter was placed into an antecubital vein, and 2 mL/kg of iopromide (Ultravist 370; Schering, Berlin, Germany) was injected with a power injector (Envision CT; Medrad, Indianola, PA) at a rate of 2.5 mL/s. The scan delay time for CT venography was set at 3 minutes after initiating injection of contrast material to allow the enhancement of the deep and superficial veins and any possible collateral vessels.

In general, the scanning parameters used for CT venography were as follows: X-ray beam collimation: 1.25–3.2 mm, reconstruction interval: 1.25–1.6 mm, X-ray tube voltage: 100 kVp and an effective tube current of 150 mAs. For the MX8000 scanner, the parameters used were 4 × 2.5-mm detector collimation, 15-mm table feed per gantry rotation, a 3.2-mm slice thickness and a 1.6-mm reconstruction interval. For the LightSpeed Ultra scanner, the parameters were 8 × 2.5-mm detector collimation, 17.5-mm table feed per gantry rotation, a 1.25–2.5 mm slice thickness and a 1.25-mm reconstruction interval. The scan range was from above the iliac bifurcation to the ankle joint.

Image Interpretation

Two radiologists, with 18 and 10 years of experience in vascular imaging, respectively, evaluated all the CT venographic images by working in consensus and using dedicated 3D software (Rapidia; Infinitt, Seoul, Korea).

At first, the presence or absence of FV and PV was recorded and the 3D relationships between the existing FV and PV and their accompanying artery were analyzed. Next, the presence or absence of variations, including multiplication, in the relationship between the femoropopliteal vein and the accompanying artery was determined and we classified the observed variations. The nomenclature of the veins of the lower limbs was described using the terms proposed by the International Interdisciplinary Consensus Committee (13). A femoropopliteal vein was defined as the segment from the femoral vein to the popliteal vein.

The evaluation was extended from the PV at the level of the knee joint space to the confluence of the femoral and deep femoral veins. In each patient, the table positions used for assessing the lower margin of the medial femoral condyle (as a landmark for the knee joint space), the extent and location of the variations and the location of the adductor hiatus, as well as the confluence of the superficial and deep femoral veins were recorded to investigate the regional differences in the pattern and frequency of the variations. The adductor hiatus, which is the lower margin of the adductor canal, was identified as the opening in the tendinous or muscular insertion of the adductor magnus muscle to the femur and this was regarded as the landmark

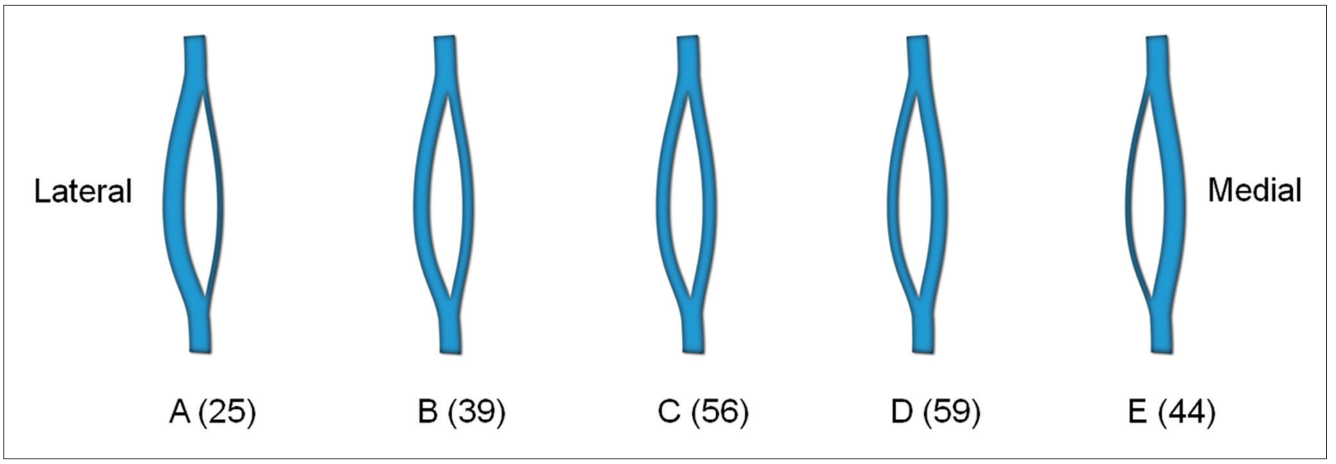


Fig. 1. Schematic drawings of different types of dominance of duplicated femoropopliteal veins. Medial channel tends to be larger.
Numbers in parentheses represent total number of limbs observed. This schematic diagram is anterior-posterior projection of right lower limb. **A.** Lateral channel is more than twice as large as medial channel. **B.** Lateral channel is 20–100% larger than medial channel. **C.** Both channels are similar in size, i.e., within 20%. **D.** Medial segment is 20–100% larger than lateral segment. **E.** Medial channel is more than twice as large as lateral channel.

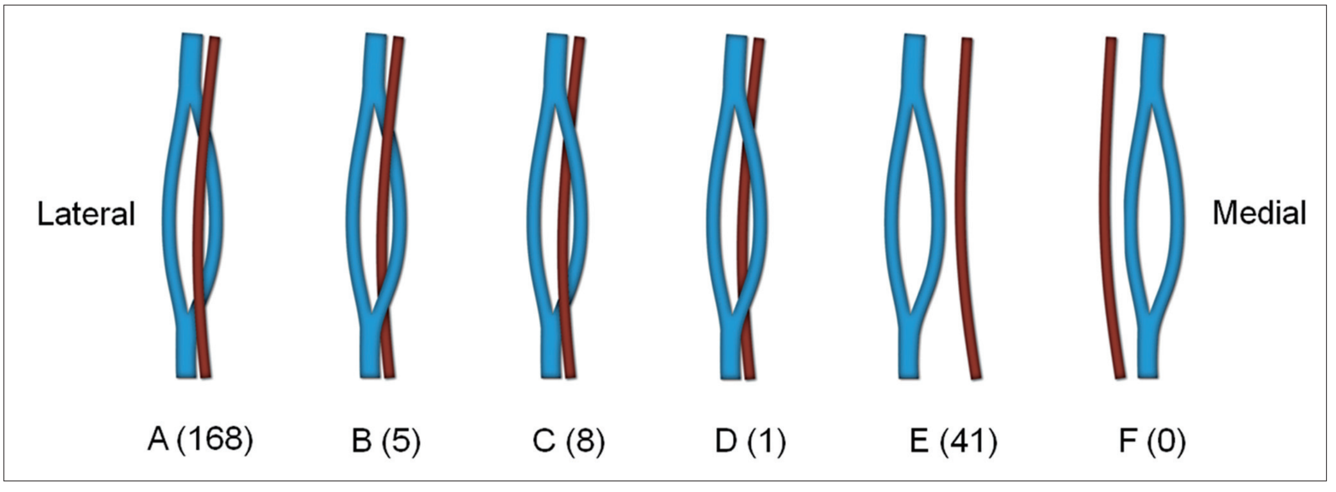


Fig. 2. Schematic drawings of different types of duplicated femoropopliteal veins and drawings reflect three-dimensional relationships with accompanying artery.
Numbers in parentheses represent total number of limbs observed. This schematic diagram is anterior-posterior projection of right lower limb. **A.** Femoropopliteal vein predominantly divides and rejoins posterior to artery, which is called bilateral post-arterial duplication as in. **B.** Femoropopliteal vein divides anteriorly and rejoins posteriorly to form circumarterial duplication. **C.** Femoropopliteal vein divides posteriorly and rejoin anteriorly to form circumarterial duplication. **D.** Femoropopliteal vein divides and rejoins anterior to artery, which is called bilateral pre-arterial duplication. **E.** Both of duplicated channels lie lateral to artery and they do not go over artery, which is called lateral duplication. **F.** Both of duplicated channels lie medial to artery and they do not go over artery. This duplication was not observed in our series.

that divided the FV and PV. The length of the affected segment with a variation was expressed as the vertical interval between the table positions provided by the CT machine, and not by the true length measured along the center path of the venous segment for practical purposes.

Multiplication of the Femoropopliteal Vein

The presence or absence of multiplication in the femoropopliteal vein was recorded as single, duplication or a complex network. Duplication was defined as the simple division of the femoropopliteal vein and reunification at the upper level. A complex network was defined as multiple parallel or interconnecting channels around the femoropopliteal artery.

In case of duplication, we analyzed the dominance of the two parallel channels as follows: (a) the lateral channel

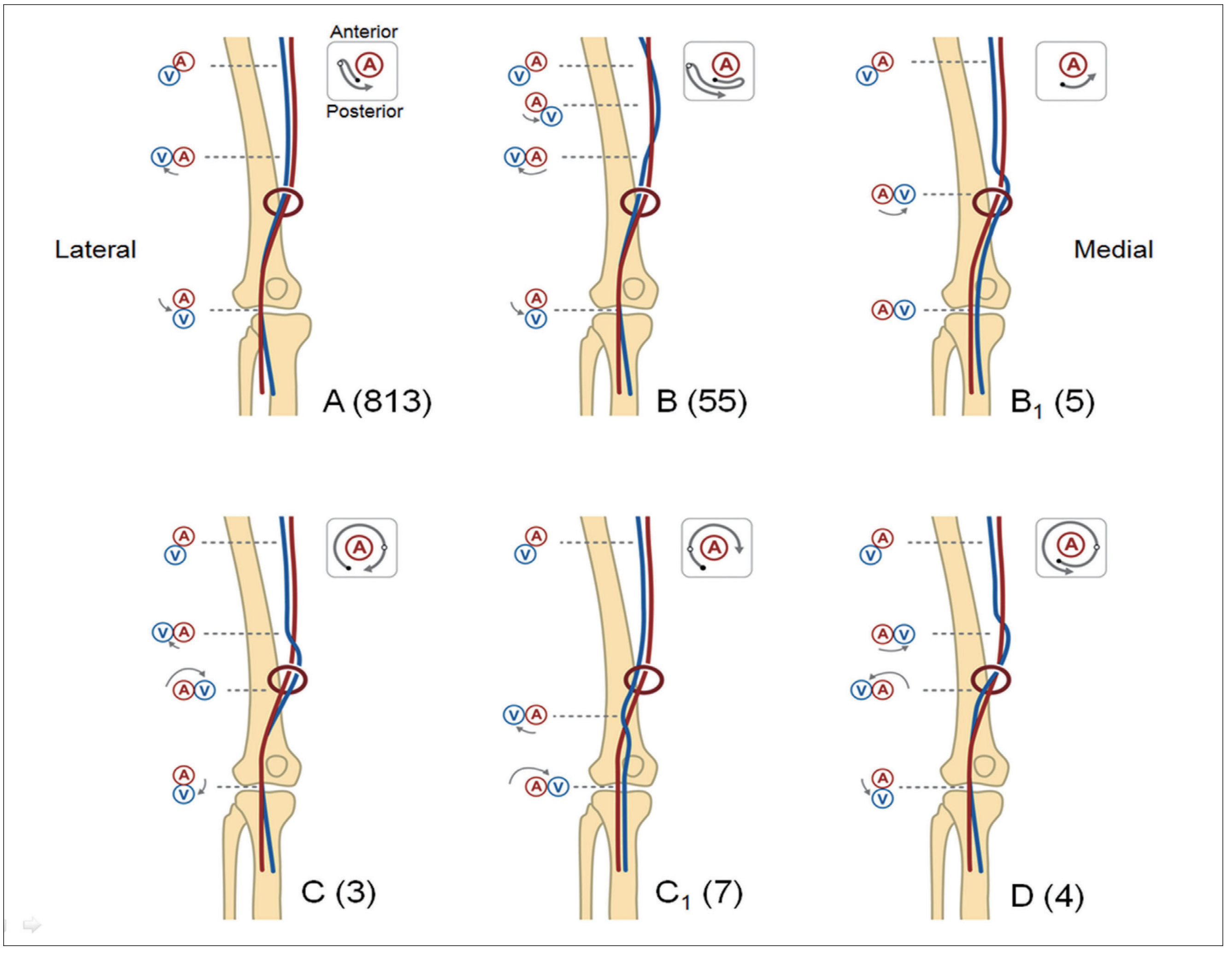


Fig. 3. Schematic drawings of different types of three-dimensional positional relationships between femoropopliteal vein and artery.
Numbers in parentheses represent total number of limbs observed. This schematic diagram is anterior-posterior projection of right lower limb. Small diagram within rectangular box represents movement of vein in relation to artery in craniocaudal direction on conventional axial projection of CT images. Black circle and white circle in box represent location of vein in relation to artery at level of proximal thigh (black circle) and at level of adductor hiatus (white circle), respectively. A indicates artery and V indicates vein.
Normal position (**A**) was considered when vein lay posterolateral to artery at upper thigh level, lateral at level of adductor hiatus and posterior at popliteal fossa. Medial malposition (**B**) was considered when femoral vein crossed over artery and became located at medial side of artery. At popliteal fossa, popliteal vein was infrequently located at medial side of artery (**B_1**). Anterior rotation (**C**) was considered when distal femoral vein continued to rotate around artery anteriorly to reach popliteal vein (clockwise in right lower limb and counterclockwise in left lower limb in craniocaudal direction, or counterclockwise in right lower limb and clockwise in left lower limb in caudocranial direction). At popliteal fossa, popliteal vein was infrequently located at medial side of artery (**C_1**). Posterior rotation (**D**) was considered when distal femoral vein continued to rotate around artery posteriorly to reach popliteal vein (counterclockwise in right lower limb and clockwise in left lower limb in craniocaudal direction, or clockwise in right lower limb and counterclockwise in left lower limb in caudocranial direction).

Table 1. Multiplication Variations in Femoropopliteal Vein (n = 890 limbs)

	Right	Left	Total	Bilaterality
Total No.	445 limbs	445 limbs	890 limbs	445 patients
Agenesis of femoropopliteal vein	1 (0.2)	2 (0.4)	3 (0.3)	0 (0)
Single	322 (72)	310 (70)	632 (71)	251 (56)
Isolated in FV	86 (19)	104 (23)	190 (21)	42 (9)
Duplication	85	102	187	
Unifocal	79	99	178	
Multifocal (double)	6	3	9	
Mean length (cm)	7.0 ± 3.7	7.4 ± 4.0	7.2 ± 3.8	
Range (cm)	0.6–18.9	0.8–19.3	0.6–19.3	
≤ 5	31	32	63	
5.1–10	44	45	89	
10.1–15	13	22	35	
15.1–20	3	6	9	
Complex network (unifocal)	1	2	3	
Length	16.3	15.5 ± 0.1	15.7 ± 0.5	
Isolated in PV	7 (2)	7 (2)	14 (2)	0 (0)
Duplication	6	6	12	
Unifocal	5	6	11	
Double	1	0	1	
Mean length (cm)	3.3 ± 1.7	4.4 ± 1.9	3.8 ± 1.8	
Range (cm)	1.3–5.8	1.8–6.9	1.3–6.9	
≤ 5	5	4	9	
5.1–10	1	2	3	
Complex network (unifocal)	1	1	2	
Length	8.6	0.9	4.8 ± 5.4	
Both in FV and PV	29 (7)	22 (5)	51 (6)	4 (0.9)
Duplication	15	12	27	
Unifocal crossing adductor hiatus	12	10	22	
Multifocal (double) in FV and PV	3	2	5	
Mean length (cm)	8.5 ± 5.5	11.4 ± 7.0	9.9 ± 6.3	
Range (cm)	1.8–25.1	2.4–23.5	1.8–25.1	
≤ 5	3	3	6	
5.1–10	8	5	13	
10.1–15	3	2	5	
15.1–20	0	1	1	
> 20	1	3	4	
Complex network	13	9	22	
Unifocal crossing adductor hiatus	13	9	22	
Length (cm)	17.8 ± 6.8	20.5 ± 4.4	18.9 ± 6.0	
Combination of duplication and complex network	1	1	2	

Note.— Data in parentheses are percentages.
FV = femoral vein, No. = number, PV = popliteal vein

is more than twice as large as the medial channel, (b) the lateral channel is 20–100% larger than the medial channel, (c) both channels are similar in size (within 20%), (d) the medial segment is 20–100% larger than the medial segment and (e) the medial channel is more than twice as large as the lateral channel (Fig. 1). In addition, their anatomic relationship with the accompanying artery was also evaluated (Fig. 2).

3D Anatomical Course and the Position of the Femoropopliteal Vein in Relation to the Artery

The anatomical course and position of the femoropopliteal vein were evaluated in relation to the accompanying artery in a craniocaudal direction, and these were classified into four types: normal position, medial malposition, anterior rotation and posterior rotation (Fig. 3). A normal position was considered when the vein lay posterolateral to the artery at the upper thigh level, lateral at the level of the adductor hiatus and posterior at the popliteal fossa. Medial malposition was considered when the FV or PV crossed over the artery and it became located at the medial side of the artery. Anterior rotation was considered when the distal FV continued to rotate around the artery anteriorly to reach the PV (clockwise in the right lower limb and counterclockwise in the left lower limb in the craniocaudal direction, or counterclockwise in the right lower limb and clockwise in the left lower limb in the caudocranial direction). Posterior rotation was considered when the distal FV continued

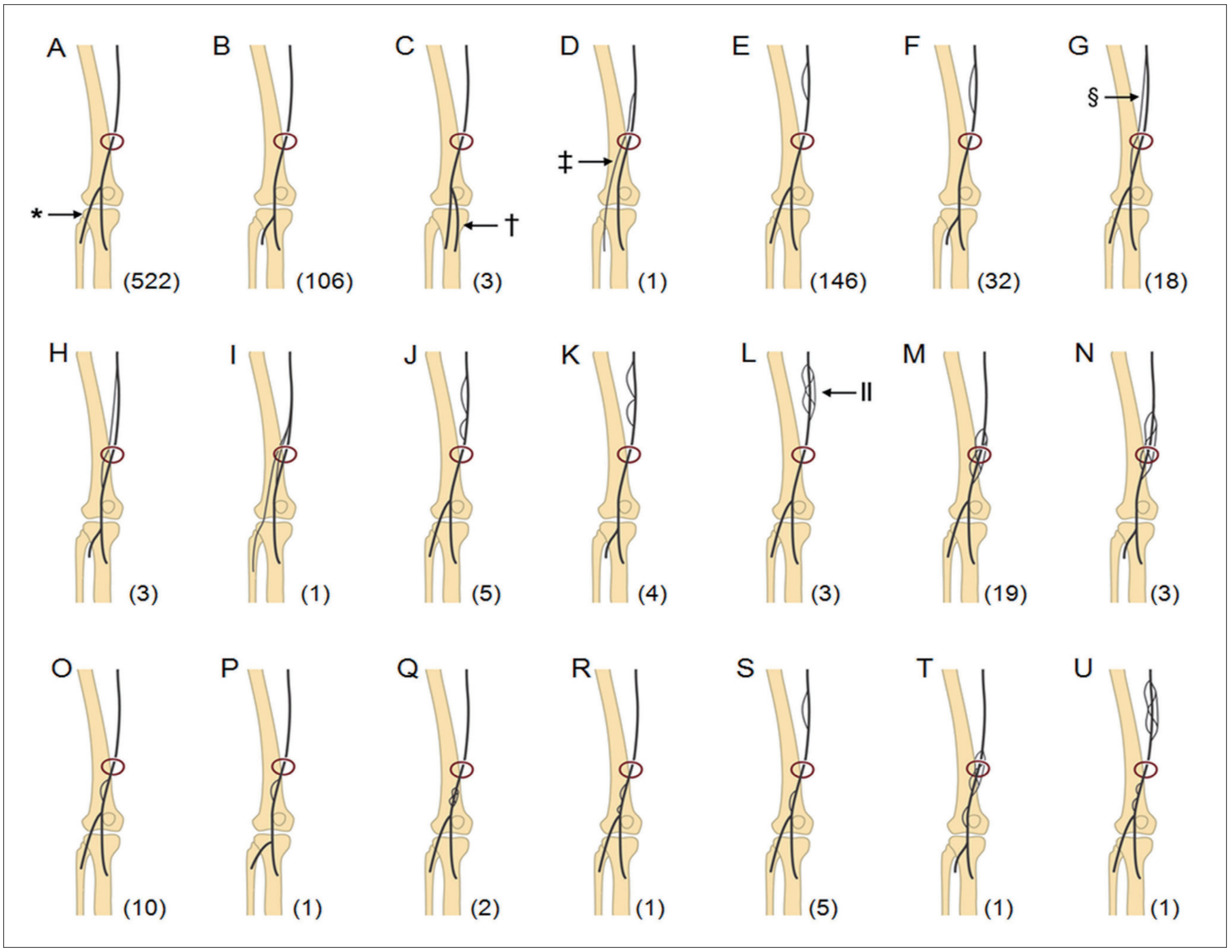


Fig. 4. Schematic drawings of different patterns of multiplication and high union of tibial veins in femoropopliteal vein, with emphasis on level of involvement in relation to adductor hiatus and multiplicity in diverse combinations.
This schematic diagram is anterior-posterior projection of right lower limb. Numbers in parentheses are total number of limbs observed. Red ring in each diagram represents location of adductor hiatus. In each diagram, * represents high union of anterior tibial vein with popliteal vein above knee joint space, † indicates high union of posterior tibial vein, ‡ indicates high union of anterior tibial vein extending up to femoral vein through adductor hiatus, § indicates duplication passing through adductor hiatus and indicates complex network.

Korean Journal of Radiology
KJR

to rotate around the artery posteriorly to reach the PV (counterclockwise in the right lower limb and clockwise in the left lower limb in the craniocaudal direction, or clockwise in the right lower limb and counterclockwise in the left lower limb in the caudocranial direction).

High Confluence of the Tibial Veins

High confluence of the tibial veins was defined as one of the tibial branches extending above the knee joint space. We recorded the name of the responsible vein and the level of the confluence using the table positions provided by the CT machine.

Regional Differences in the Variation of the Femoropopliteal Vein

In each patient, we recorded the table positions for the knee joint space (represented as the lower margin of the medial femoral condyle), the adductor hiatus and the confluence of the superficial and deep femoral veins, as well as the extent and location of the observed variations. We transformed the observed data into a standard format by assuming that the length of the femoropopliteal vein (from the confluence of the superficial and deep femoral veins to the lower margin of the medial femoral condyle) was the same in every patient (the level of confluence was represented as 0 and the level of the lower margin of the medial femoral condyle was represented as 100), and we calculated the relative location (in percentiles) of the observed variations.

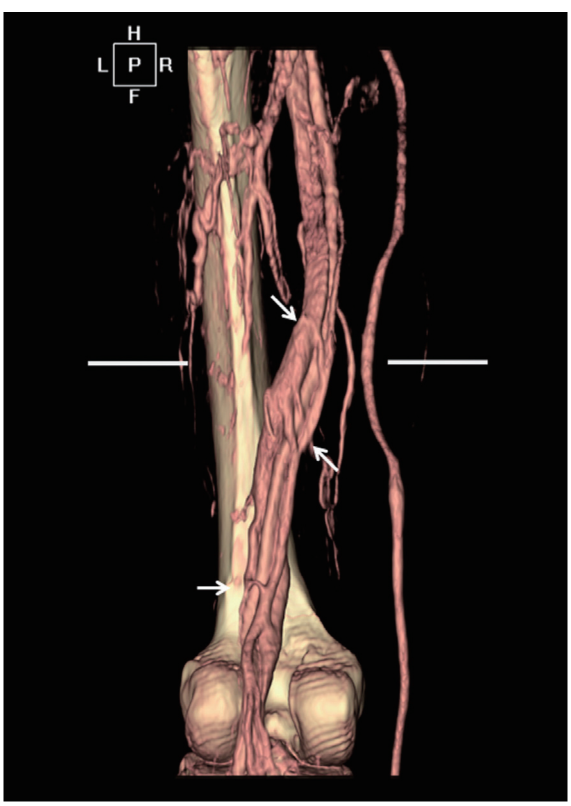
By summing up the transformed data, we calculated the frequency of the variations at each relative position (in percentiles) along the femoropopliteal vein and we assessed the regional differences in the variations of the femoropopliteal vein.

Statistical Analysis

Comparisons of the continuous variables between the two groups were assessed using the Student *t*-test. Differences in the frequencies between the two groups were tested by Fisher's exact test. The statistical analysis was performed using commercially available software (InStat, version 3.0; GraphPad Software, San Diego, CA). Differences were considered significant when the *p* value was less than 0.05.

RESULTS

There were four distinct categories of variations: agenesis, multiplication, variations of the anatomical course and high



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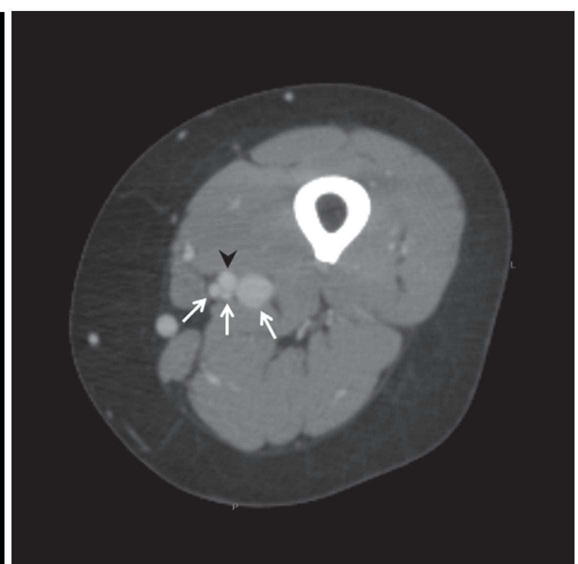


B

Fig. 5. Images obtained in 58-year-old male with complex network of left femoropopliteal vein.
A. Three-dimensional volume rendered image in posterior view clearly demonstrates long segmental complex channels (arrows) of femoropopliteal vein. **B.** Transverse axial image at level of white line (**A**) shows multiple femoral veins (arrows) posterior to artery (arrowhead). F = foot, H = head, L = left, P = posterior, R = right.

union of the tibial veins.

Agenesis of the Femoropopliteal Vein

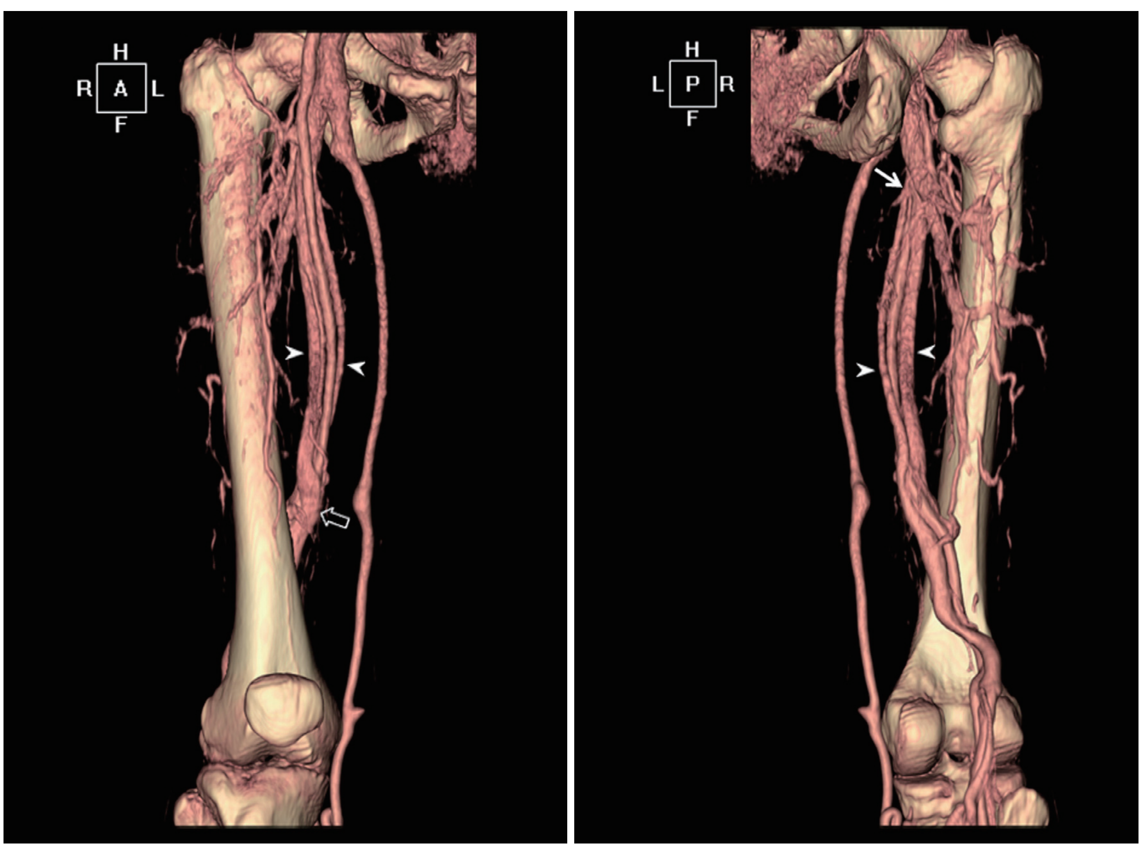
In 445 patients, three patients (0.7%) had neither a FV nor a PV (one in the right leg and two in the left legs) because they had a persistent sciatic vein instead of the femoropopliteal vein.

Multiplication of the Femoropopliteal Vein

Multiplication of the femoropopliteal vein was observed in 255 limbs of 191 patients. Multiplication could be further subclassified according to its complexity, its relationship with the artery and the dominance of the duplicated channels. Duplication was observed in 228 limbs of 178 patients and a complex network was observed in 29 limbs of 29 patients. The details of the multiplication variations in the FV and PV are summarized in Table 1. Figure 4 illustrates the diverse patterns of the multiplication variations of the femoropopliteal vein found in 890 limbs.

Regarding the FV multiplications with including the cases involving the adductor hiatus, 241 (27%) of 890 limbs had multiplication variations: duplications in 214 (89%) limbs and complex networks in 27 (11%) (Fig. 5). For the PV, multiplication variation was found in 21 (2%) of 890 limbs: duplications were found in 19 (91%) limbs and complex networks were found in two (10%). Overall, 255 (29%) of 890 limbs had multiplication variations in either the FV or PV: in an isolated FV (n = 190), in an isolated PV (n = 14) and in both the FV and PV (n = 51). Among the 445 patients, 117 (26%) had multiplication variations in either the right or left FV (including the cases involving the adductor hiatus). Bilateral involvement was noted in 60 (14%) patients. If the entire femoropopliteal vein was considered, 127 (29%) patients had multiplication variations in a single limb. Bilateral involvement was observed in 64 (14%) patients. Two hundred fifty one (56%) patients had a single FV and PV in both limbs.

The mean length of multiplication in the FV was 8.7 ±



A B

Fig. 6. Images obtained in 63-year-old female with duplication of right femoral vein.
A, B. Three-dimensional volume rendered images in anterior (**A**) and posterior view (**B**) shows long segmental duplication (arrowheads) involving femoral vein. Femoral vein divides anteriorly (open arrow) and rejoins posteriorly (arrow), forming circumarterial duplication. A = anterior, F = foot, H = head, L = left, P = posterior R = right.

Korean Journal of Radiology
KJR

5.5 cm: 7.6 ± 4.3 cm for the duplications and 18.5 ± 5.3 cm for the complex networks. The involved segments of the complex networks were significantly longer than those of the duplications (p < 0.0001 in both limbs). Compared with the duplications, the complex networks more frequently involved the adductor hiatus (p < 0.0001 in both limbs).

On the analysis of the dominance of the two parallel channels in the FV duplications, the medial channels tended to be larger than the lateral channels in both limbs (Fig. 1). Of the 223 duplicated FVs, 103 (46%) cases had larger medial channels, 64 (29%) had larger lateral channels and the remaining 56 (25%) had duplicated channels of similar size. Very small duplicated channels less than 3 mm in diameter were found in three cases of the medial channels and in seven cases of the lateral channels.

The duplicated channels had diverse 3D relationships with the accompanying artery, and these are illustrated in Figure 2. The duplicated channels predominantly lie at both sides of the accompanying femoropopliteal artery, and the femoropopliteal vein divides and rejoins posterior to the artery. However, circumarterial (Fig. 6), lateral or pre-arterial duplications were also observed in 13, 41 and one cases, respectively. For the 29 complex networks, the circumarterial type was observed in five cases.

Anatomical Course Variations

In terms of the anatomical course variations, medial malposition was found in 27 (6%) right limbs and in 33 (7%) left limbs, anterior rotation was found in six (1%) right limbs and in five (1%) left limbs, and posterior rotation was found in two (0.4%) of each limb (right and left) (Table 2). Medial malposition was found above the adductor hiatus or

Table 2. Variations in Anatomical Course and Position of Femoropopliteal Vein in Relation to Accompanying Artery

	Medial Malposition	Anterior Rotation	Posterior Rotation
Right (n = 445 limbs)			
Location	27	6	2
Above adductor hiatus	15	0	0
Through adductor hiatus	12 (5)	3 (1)	2
Below adductor hiatus	0	3 (3)	0
Length			
Mean length (cm)	13.1 ± 5.7	12.3 ± 3.7	12.3 ± 0.2
Above adductor hiatus	11.1 ± 5.5		
Through adductor hiatus	15.6 ± 5.1	14.5 ± 4.4	12.3 ± 0.2
Below adductor hiatus		10.1 ± 0.8	
Range (cm)	3.9–22.7	9.3–18.4	12.1–12.4
Associated multiplication in affected level	5	1	1
Left (n = 445 limbs)			
Location	33	5	2
Above adductor hiatus	20	1	0
Through adductor hiatus	13	1 (1)	2
Below adductor hiatus	0	3 (2)	0
Length			
Mean length (cm)	13.3 ± 5.3	14.7 ± 10.2	16.0 ± 2.0
Above adductor hiatus	11.9 ± 5.3	12.3	
Through adductor hiatus	15.6 ± 4.7	32.5	16.0 ± 2.0
Below adductor hiatus		9.6 ± 2.4	
Range (cm)	0.4–26.6	7.3–32.5	14.6-17.4
Associated multiplication at affected level	8	3	1

Note.— Data in parentheses indicate number of limbs in which popliteal vein was located medial to popliteal artery.

through the hiatus. However, anterior rotation or posterior rotation was commonly found through or below the adductor hiatus (Figs. 7, 8). Of the 633 limbs having both a single FV and PV (if high confluence of the tibial veins was not considered), 584 (92%) limbs showed a normal position. Two hundred twenty (49%) of 445 patients had bilateral single FV and a single PV in the normal position. In five of 60 limbs with medial malposition and in seven of 11 limbs with anterior rotation, the popliteal vein was persistently located medial to the accompanying popliteal artery.

High Confluence of the Tibial Veins

High confluence of the tibial veins was found in 737 (83%) limbs: 369 in the right limb and 368 in the left limb (Table 3). In almost all cases with high confluence of the tibial veins, the anterior tibial veins extended above the knee joint space, except in the three cases in which the posterior tibial veins extended above the knee joint space. One of the tibial branches extended above the adductor hiatus in two cases. The mean length of the tibial vein extending above the knee joint space was 2.2 cm ± 1.9 (range: 0.1–17.4 cm): 2.2 cm ± 2.2 (range: 0.1–17.4 cm) in the right limb and 2.3 cm ± 1.6 (range: 0.1–9.1 cm) in the left limb.

Regional Differences of the Variations of the Femoropopliteal Vein

Figure 9 graphically displays the frequency of the variations at each relative position (in percentiles) along the femoropopliteal vein. The graph clearly demonstrates regional differences. Simple duplication was most commonly located in the mid-FV without crossing the adductor hiatus. In contrast, variations of the anatomical course and complex networks tended to be relatively evenly and widely distributed around the adductor canal. High union of the tibial veins rarely extended beyond the adductor hiatus.

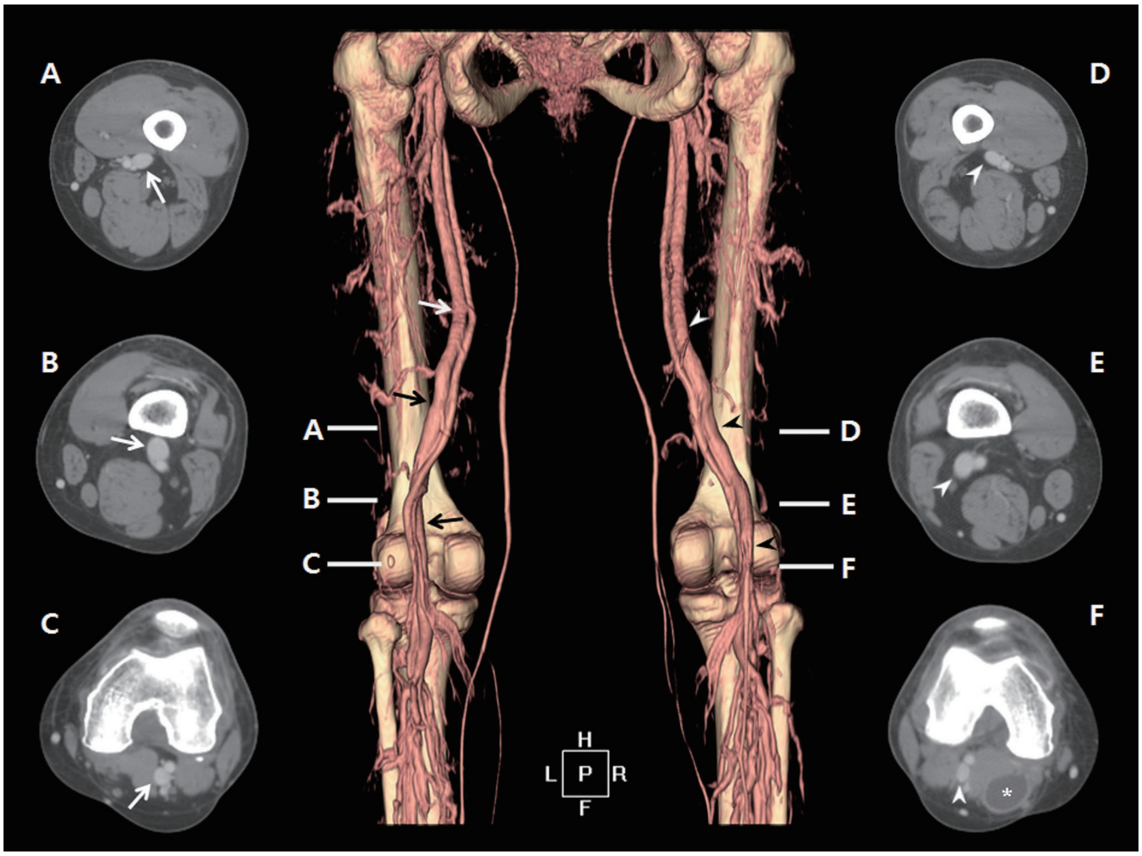


Fig. 7. Images obtained in 50-year-old female with normal position of right femoropopliteal vein and anterior rotation of left femoropopliteal vein.
3D volume rendered image in posterior view nicely visualizes overall 3D positional relationship between femoropopliteal vein and artery. Below adductor hiatus, left femoropopliteal vein (arrows) rotates around artery anteriorly. Right femoropopliteal vein (arrowheads) is located lateral at level of adductor hiatus (D), and posterior at popliteal fossa. Baker's cyst (*) was incidentally visualized in right popliteal fossa. Lines A and D indicate level of adductor hiatus. F = foot, H = head, L = left, P = posterior, R = right.

Korean Journal of Radiology
KJR

DISCUSSION

In the present study, we performed a comprehensive analysis of the FV and PV anatomy using CT venography in order to assess the positional variations as well as multiplicity in relation to the accompanying artery. We believe the present study using CT has several strengths over the previous studies that used US or venography. The advantages of CT over US lie in its short examination time, the lack of operator dependence and the ability to study deep seated structures. Compared to conventional venography, CT has the advantages of allowing evaluation of the 3D relationships with the accompanying artery and adjacent structures. Furthermore, because of the high z-axis spatial resolution of CT, high quality 3D images or multiplanar reconstruction images can provide a venous

Table 3. High Confluence of Tibial Vein (n = 890 limbs)

	Right	Left	Total	Bilaterality
Total Number	445 limbs	445 limbs	890 limbs	445 patients
High confluence	369 (80)	368 (80)	737(83)	311 (70)
Mean length above femoral medial condyle (cm)	2.2 ± 2.2	2.3 ± 1.6	2.2 ± 1.9	
Range above femoral medial condyle (cm)	0.1–17.4	0.1–9.1	0.1–17.4	

Note.— Data in parentheses are percentages.

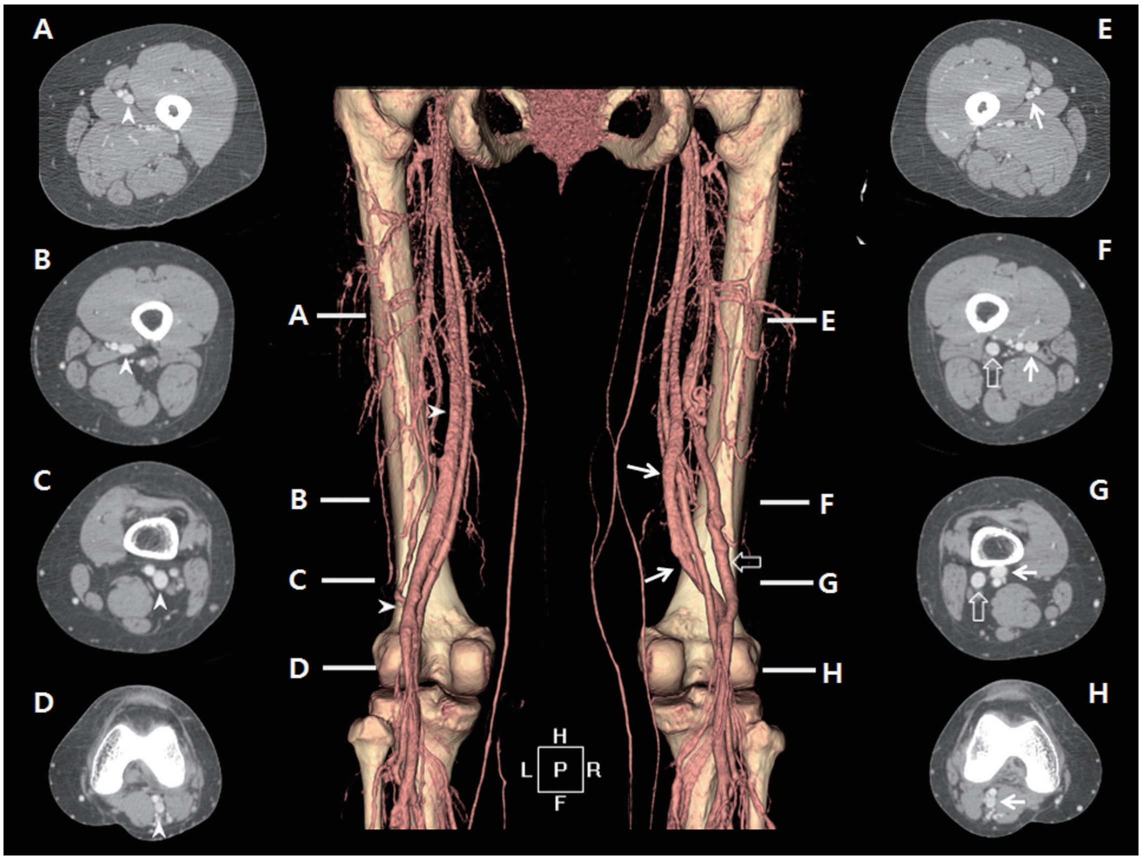


Fig. 8. Images obtained in 50-year-old female with posterior rotation of right femoropopliteal vein and normal position of left femoropopliteal vein.
3D volume rendered image in posterior view nicely visualizes overall 3D positional relationship between femoropopliteal vein and artery. Around adductor hiatus, right femoropopliteal vein (arrows) rotates around artery posteriorly and it continues to rotate anteriorly around artery (more than 360 degree counterclockwise rotation in craniocaudal direction). Incomplete persistent sciatic vein (open arrow) is also noted in right limb. Left femoropopliteal vein (arrowheads) is located posterolateral at mid thigh level, lateral at level of adductor hiatus and posterior at popliteal fossa. Lines B and F indicate level of adductor hiatus. F = foot, H = head, L = left, P = posterior, R = right.

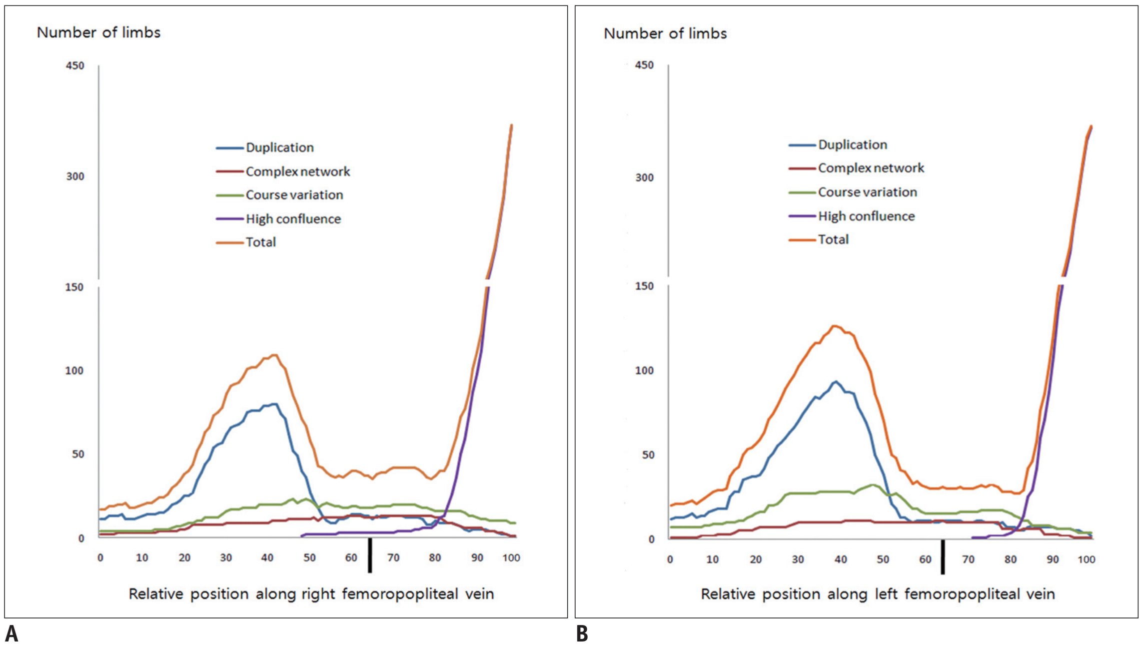


Fig. 9. Regional frequency of anatomical variations along right and left femoropopliteal veins.
X-axis indicates relative position (in percentiles) along right (**A**) and left (**B**) femoropopliteal veins under assumption that length of femoropopliteal vein (from confluence of superficial and deep femoral vein to lower margin of medial femoral condyle) is same in every patient. Level of femoral vein confluence is represented as 0 and level of knee joint space is represented as 100. Black bar on x-axis indicates average relative location of adductor hiatus (64th percentile in right limb and 63rd percentile in left limb). Graphs clearly demonstrate regional differences in frequency of variations in femoropopliteal vein. Simple duplication is most commonly located in mid-FV without crossing adductor hiatus. In contrast, variations of anatomical course and complex networks tend to be relatively evenly and widely distributed around adductor canal. High union of tibial veins rarely extends beyond adductor hiatus.

map similar to that obtained with conventional venography.

The reported incidence of multiple FVs has varied between 6% and 38% depending on the study population and the employed modalities (1–4, 6–8). The US studies have consistently demonstrated lower rates (6–25%) of multiple FVs compared to that of the venographic studies, which have reported rates of 31% and 33% (3, 8). In our study using CT, multiple FVs were found in 27% of the limbs, and 29% of the limbs had either multiple FVs or PVs. Our results are similar to those results of the venographic studies. The present study also demonstrated that 40% of the patients had multiple FVs and 43% of the patients had multiple FVs or PVs in either leg. Our per-patient results are similar to that of Screaton et al. (5), who examined 381 venograms and found that 46% of their patients had duplicated or multiple FVs. With respect to the length of the duplicated FVs, our results are in concordance with those of Quinlan et al. (8), who reported that 6–15 cm was the most common length found in 62% of the duplicated FVs.

A high confluence of the tibial branch above the knee joint space was found in as many as 83% of the legs in our study. Our rate is much higher than that of a previous study, which reported 35% (8), although a similar bone landmark of the knee joint space was used for the evaluation of high confluence. We assume that many cases might have been missed in their series of conventional venography since some of the tibial vessels did not fill with contrast material (8). On the other hand, the incidence of true duplication of the PV in our study was as low as 2%, which was slightly lower than those incidences reported in previous studies (4% and 5%) (7, 8).

There have been no previous studies that have focused on the positional variations of the FV or PV to the respective artery. In most traditional anatomy textbooks, the femoral vein is described as lying posterolateral to the artery and it does not reach the medial side of the artery until it has been joined by the deep femoral vein (14). However, our data found that 7% (64 of 890) of the FVs or PVs lie medial to the artery before it is joined by the deep femoral vein. In addition, the medial segment of the duplicated FVs tends to be larger than the lateral segment and the medial segment of the duplicated FVs almost runs medial to the artery. We postulate that a medial malposition of the FV or PV could be an extreme type of duplication that shows complete regression of the lateral segment. Even though we cannot provide the embryological backgrounds of all the observed variations, we believe that the comprehensive list of the 3D variations of the femoropopliteal vein can provide new insight into formulating a hypothetical developmental model for the lower extremity venous systems.

The present study has several clinical implications. First, comprehensive and systematic knowledge about the spectrum and 3D anatomy of the femoral and popliteal vein variations can be useful for the accurate interpretation of CT images and ultrasound exams of the lower extremities. When performing CT interpretation or US examination for suspected DVT, recognition of partial thrombosis in one of the duplicated venous channels or the presence of duplicated channels with complete occlusion due to DVT may not be easy if radiologists are unaware of their possibilities (5, 15, 16). In patients with a complex network, this complex network can be misinterpreted as a stenosis or the chronic sequelae of DVT because the involved segment of the femoropopliteal vein is divided into multiple small channels (17). In addition, a venographic study of 337 limbs in 256 patients found that the incidence of DVT was two times higher than that in the limbs with a single femoral vein (3). Therefore, it is important for physicians who perform CT or venography and who interpret the results that they be familiar with the normal lower extremity venous anatomy and its variations. Second, the diverse femoral and popliteal vein variations observed in our study may be helpful for planning interventional procedures. The recognition of duplicated channels in the completely thrombotic femoropopliteal vein can lead to the complete recanalization of the duplicated channels. The popliteal approach by puncturing the popliteal artery or popliteal vein is frequently used for the interventional management of DVT and infrainguinal arterial occlusive diseases. To avoid the complications of popliteal vascular access, knowledge about the normal anatomical relationship and the variations between the popliteal artery and vein is essential.

Our study has several limitations. First, by excluding the patients who had acute or chronic DVT, the assessed incidence of duplication might have been lower than the true incidence because duplicated or complex veins are regarded as being more prone to developing DVT (3). Second, our calculations of the FV length should be regarded as estimates. Our calculated lengths using the table points are assumed to be slightly shorter than the real length as the femoral vein runs oblique.

In conclusion, CT venography can comprehensively and systematically describe in detail the 3D anatomy of the known or newly found FV and PV variations in relation to the accompanying artery. CT venography confirmed a high incidence of variations in the lower limb venous anatomy and it also revealed various venous positional anomalies in relation to the respective artery.

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