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Variations in the branching pattern of the popliteal artery: a CT angiography study

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Abstract

Objectives: The aim of this study was to reveal the different branching patterns of the popliteal artery by computed tomography angiography (CTA) in a large sample.

Methods: CTA images of 1500 lower extremities of 750 patients (603 males, 147 females) with a mean age of 56.4±19.6 were evaluated retrospectively. The variations in the branching pattern of the popliteal artery and the frequency of these variations were examined and classified under three main types.

Results: Type I–A was observed in 1422 extremities (94.8%) and noted as the most common branching pattern of the popliteal artery; Type I–B and Type I–C was observed in 39 extremities (2.6%); Type II in 37 extremities (2.4%) and Type III in 2 extremities (0.1%). The bilateral incidence of Type I–A was 90.8%. The incidence of bilateral variation was 0.4% for Type I–B and 0.1% for Type II–B. No statistically significant difference was found in terms of side and gender.

Conclusion: Evaluation of lower extremity arteriograms is important in the diagnosis and surgery of peripheral vascular diseases. For this reason, it is important to know the branching pattern of the popliteal artery. We believe that the classification system that we used will be useful in evaluating the different variations, particulary the branching levels of the branches of the popliteal artery.

Keywords: computed tomography angiography; fibular artery; popliteal artery; tibial artery; variation

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Introduction

The popliteal artery is the continuation of the femoral artery in the popliteal fossa and feeds the leg and foot. The popliteal artery extends to the lower border of the popliteus muscle in the popliteal fossa.[1,2] Here it divides into 2 branches, which are defined as the anterior tibial artery and the tibial-fibular trunk. The posterior tibial artery and its branch; the fibular artery, emerges from this trunk.[3] Anterior tibial artery passes to the anterior compartment of the leg by passing through an opening in the superior part of the interosseus membrane. Continuing distally, it extends on the dorsal side of the foot, and here it is named as dorsalis pedis artery.[4] The posterior tibial artery starts from the lower border of the popliteus muscle as the terminal branch of the popliteal artery and approaches to the tibia while continuing distally as lateral and medial plantar arteries underneath the abductor hallucis muscle.[5] The fibular artery is deeply located on the back of the leg, close to the fibular area. Developmental distress of embryological structures contributes to variations in the branching pattern of the arteries.[6] The variations regarding the branching of the popliteal artery are common.[7] Knowing the normal anatomical course and variations of the popliteal artery in the diagnosis of clinical applications such as arteriosclerosis, vascular graft surgeries, direct surgical repair, transluminal angiography, embolectomy or arterial injuries is important for a successful evaluation and management of peripheral vascular diseases.[7–11] Although the branching pattern of the popliteal artery is subject to wide range of variations, there are limited studies done on large

This study was an oral presentation at the 19th National Anatomy Congress &1st International Mediterranean Anatomy Congress (IMAC), 6th–9th September 2018, Konya, Turkey number of samples. Therefore; the aim of this study was to reveal the possible different branching patterns of popliteal artery belonging to different genders by computed tomography angiography (CTA) in a large number of samples.

Materials and Methods

CTA images of 1550 lower extremities of 775 patients were evaluated retrospectively. However, 50 of 1550 extremities were excluded from the study due to reasons such as atherosclerosis, artifacts and vascular occlusion. Thus, branching pattern and variations of the popliteal artery in 1500 extremities of 750 patients (603 males, 147 females) with a mean age of 56.4±19.6 were examined. The scans were performed using a 256-slice dual-source scanner (SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany) with a collimation of 128 mm × 0.6 mm, a pitch of 1.2. The standard scanning parameters were set to 120 kVp and 80 mAs. The main data sets were reconstructed in to axial slices of 1 mm thickness. Images of popliteal artery and its branches were analyzed via post-processing software (Snygo Via, Siemens, Germany).

The classification method suggested by Kim et al.[10] was used to evaluate the popliteal artery. The characteristic of this branching pattern is as follows:

- **Type I:** The popliteal artery divides into braches at the lower border of the popliteus muscle. In Type I–A; the popliteal artery branches into 2 as anterior tibial artery and tibiofibular trunk. In this pattern the tibiofibular trunk gives rise to posterior tibial artery and fibular artery. This pattern is regarded as the regular type. If tibiofibular trunk is absent and if anterior tibial artery, posterior tibial artery and fibular artery form a root together, it is defined as trifurcation or Type I–B. If the first branch of the popliteal artery is the posterior tibial artery, it is considered as Type I–C. In this subtype, the tibiofibular trunk branches into anterior tibial artery and fibular artery[10] (**Figure 1**).

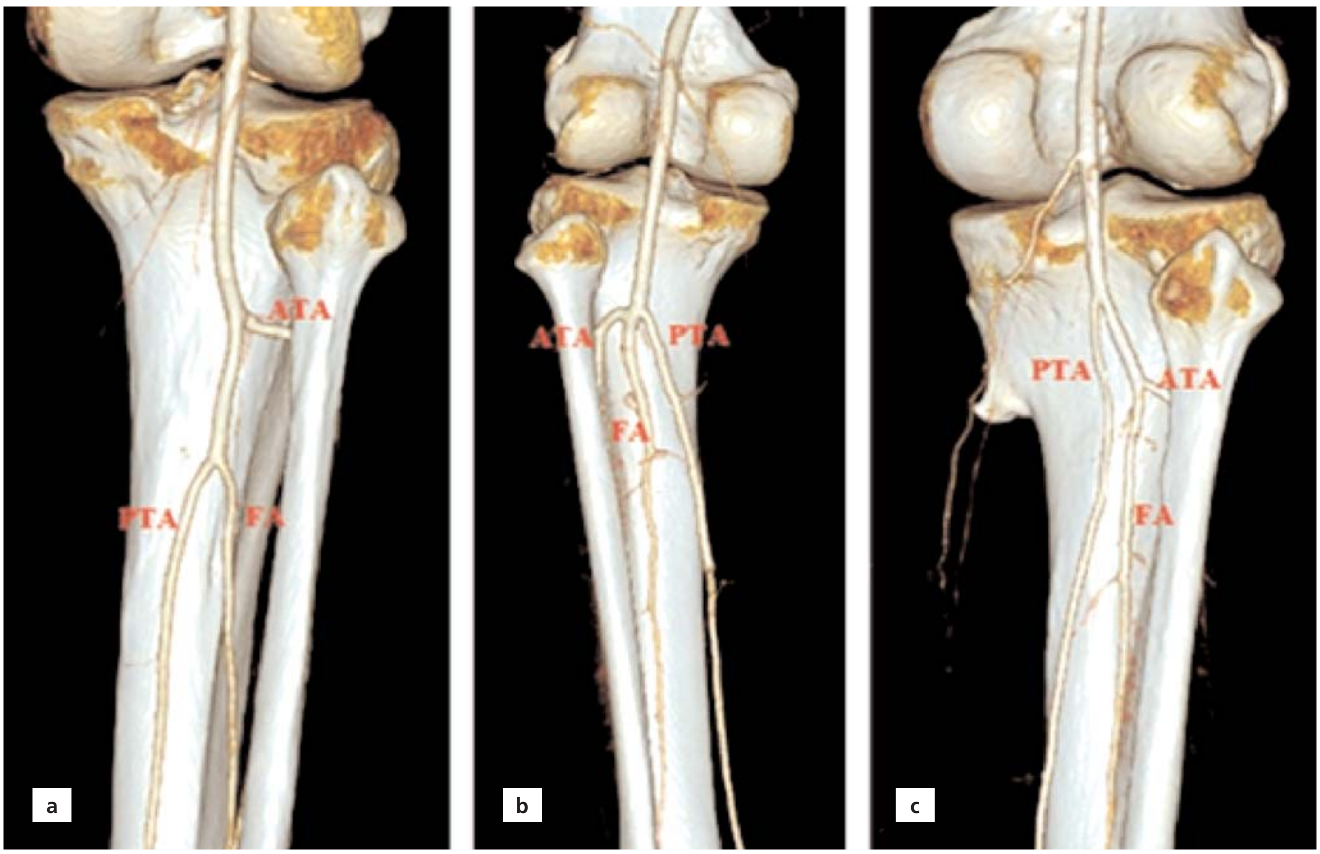

Figure 1. Type I subgroups in CTA images. (**a**) Type I-A branching pattern in a 69-year-old male. Note that anterior tibial artery (ATA) is the first branch, and posterior tibial artery (PTA) and fibular artery (FA) are arising from a common root; (**b**) Type I-B branching pattern in a 60-year-old male. ATA, PTA and FA diverge directly from the popliteal artery; (**c**) Type I-C branching pattern in a 67-year-old male. PTA is the first branch of the popliteal artery. ATA and FA are arising from a common root.

- **Type II:** Popliteal artery branches above the popliteus muscle. In Type II–A1; the anterior tibial artery branches superior to the knee joint; In Type II–A2, the anterior tibial artery branches from the popliteal artery at the knee level and its proximal part makes an arc. In Type II–B, the first branch of the popliteal artery is the posterior tibial artery. Anterior tibial artery and fibular artery originate from the common root. Finally, in Type II–C, the fibular artery, branches out superior or at the level of the knee joint. Anterior tibial artery and posterior tibial artery also originate from a common trunk[10] (**Figure 2**).
- **Type III:** The popliteal artery has a hypoplastic or aplastic branching as a result of the change in distal blood supply. Type III–A is defined as the hypoplastic-aplastic posterior tibial artery, where there is only distal part of the posterior tibial artery which originates from the fibular artery (**Figure 3**). Type III–B is defined as the hypoplastic-aplastic anterior tibial artery, where the dorsalis pedis artery originates from the fibular artery. Type III–C is defined as hypoplastic-aplastic anterior tibial artery and posterior tibial artery, where the distal part of the anterior tibial artery and the posterior tibial artery originate from the fibular artery.[10]

The data were evaluated using IBM SPSS (Statistical Package for Social Sciences) for Windows (Version 21, Chicago, IL, USA). Descriptive statistics were given as number of units (n), percentage (%). Age distribution was given as mean±standard deviation and median values. Comparisons of gender according to variation types were evaluated with Fisher's exact test in 2×2 and r × c tables.[12] A p-value <0.05 was considered as statistically significant.

Results

The study included CTA images of 603 males (80.4%) and 147 females (19.6%). The ages of the patients ranged from 7–91 years, with an average age of 56.4±19.6 (median: 59.0

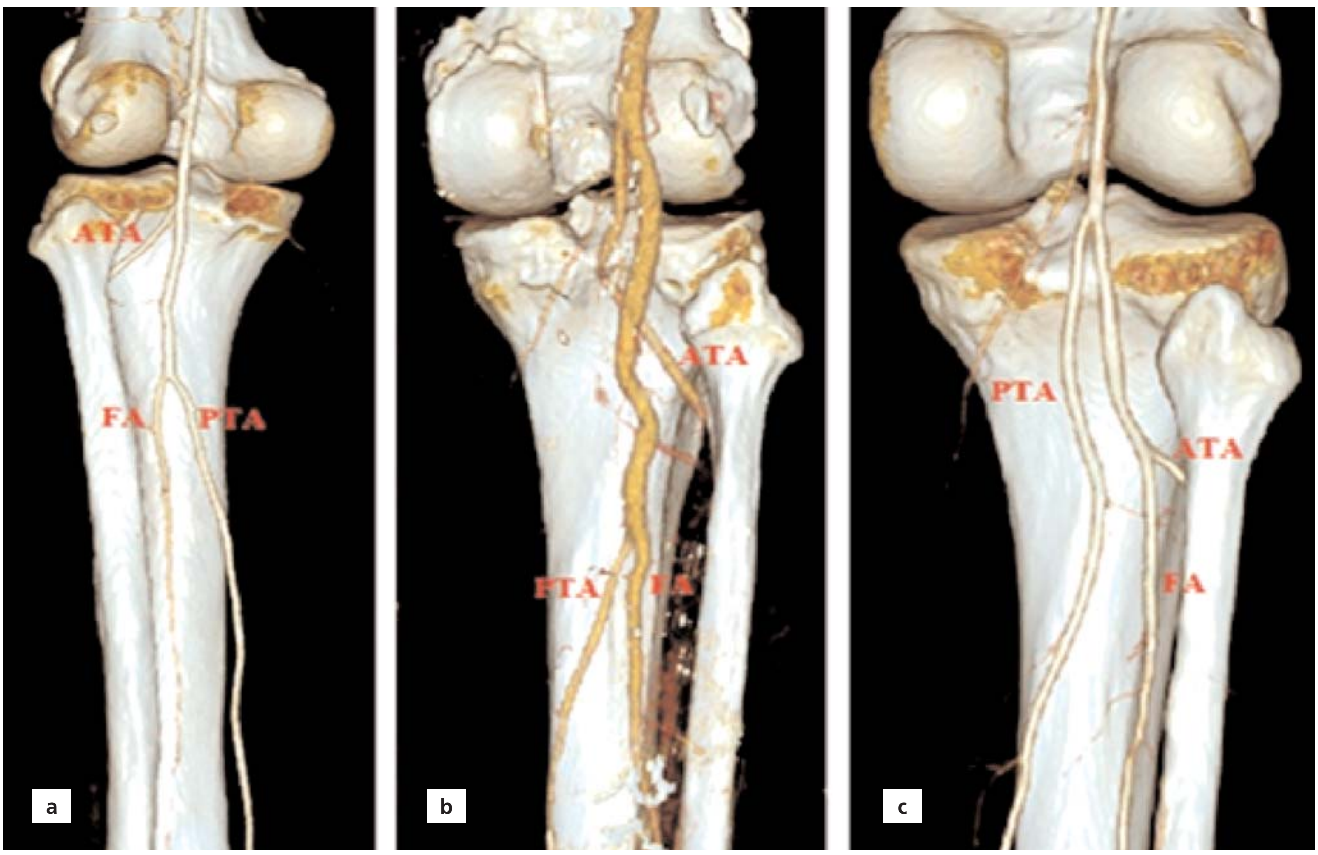

Figure 2. Type II subgroups in CTA images. (**a**) Type II-A1 branching pattern in a 71-year-old male where anterior tibial artery (ATA) branched at a high (proximal) level; (**b**) Type II-A2 branching pattern in an 83-year-old male with high branching of ATA making a medial curve initially and then turning laterally; (**c**) Type II-B branching pattern in a 67-year-old male where posterior tibial artery (PTA) branched at a high (proximal) level. FA: fibular artery.

Figure 3. Type III-A branching pattern in CTA image of a 54-year-old woman. *Hypoplastic posterior tibial artery. **ATA:** anterior tibial artery; **FA:** fibular artery.

years). Out of 750 patients 709 (94.5%) had Type I–A, 19 (2.5%) had Type I–B and 11 (1.5%) had Type II–A1 branching pattern on the left side. And 713 (95.1%) had Type I–A, 12 (1.6%) had Type II–B and 11 (1.5%) had Type I–B branching pattern on the right side. Bilateral evaluation revealed that 681 (90.8%) had Type I–A, 3 (0.4%) had Type I–B and 1 (0.1%) had Type II–B branching pattern. The total number of patients with bilateral variation was 4 (0.5%), and the total number of extremities was 8 (0.5%). The total number of patients with unilateral variation was 65 (8.7%), and the total number of extremities was 130 (8.7%) (**Table 1**).

Statistical analysis revealed no difference in branching pattern in terms of sides of the extremities (p=0.701) (**Table 2**) and in terms of the gender (p=0.165) (**Table 3**). However the branching pattern in different sides showed a statistically different distribution in terms of gender (p=0.032). The frequency of bilateral branching pattern in females was significantly higher than in males. The frequency of unilateral branching pattern in males was statistically higher than in females (**Table 4**).

Discussion

Vascular development in the embryonic period determines anatomical diversity. Most of the variations are expressed by some combinations such as persistent primitive arterial segment, abnormal fusion, segmental hypoplasia or segmental aplasia.[9] Knowing the anatomy of these variations is very essential for radiological planning and surgical interventions.[13,14] While the vascular system of the lower extremity was investigated on limited number of cadavers in some of the previous studies,[15,16]

Table 1

Branching pattern in left and right legs of 750 patients.

	Right Leg															
	Type I-A		Type I-B		Type I-C		Type II-A1		Type II-A2		Type II-B		Type III-A		Total	
Left Leg	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Type I-A	**681**	**90.8**	6	0.8	2	0.3	8	1.1	1	0.1	10	1.3	1	0.1	709	94.5
Type I-B	15	2.0	**3**	**0.4**	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	19	2.5
Type I-C	4	0.5	1	0.1	**0**	**0.0**	1	0.1	0	0.0	0	0.0	0	0.0	6	0.8
Type II-A1	10	1.3	0	0.0	0	0.0	**0**	**0.0**	0	0.0	1	0.1	0	0.0	11	1.5
Type II-A2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Type II-B	2	0.3	1	0.1	0	0.0	0	0.0	0	0.0	**1**	**0.1**	0	0.0	4	0.5
Type III-A	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	**0**	**0.0**	1	0.1
Total	713	95.1	11	1.5	3	0.4	9	1.2	1	0.1	12	1.6	1	0.1	750	100

n: Number. Bilateral (right and left) values are shown in bold font.

Table 2
Comparison of branching pattern in left legs in terms of gender.

	Males (n=603)		Females (n=147)		Test statistics	
Subtype	n	%	n	%	X^2	p
Type I-A	567	94.0	142	96.6	2.953	0.701
Type I-B	16	2.6	3	2.0		
Type I-C	6	1.0	0	0.0		
Type II-A1	9	1.5	2	1.4		
Type II-B	4	0.7	0	0.0		
Type III-A	1	0.2	0	0.0		

Table 3
Comparison of branching pattern in right legs in terms of gender.

	Males (n=603)		Females (n=147)		Test statistics	
Subtype	n	%	n	%	X^2	p
Type I-A	569	94.3	144	97.9	9.170	0.165
Type I-B	10	1.7	1	0.7		
Type I-C	3	0.5	0	0.0		
Type II-A1	9	1.5	0	0.0		
Type II-A2	1	0.2	0	0.0		
Type II-B	11	1.8	1	0.7		
Type III-A	0	0.0	1	0.7		

the studies done on radiological images made it possible to observe the arterial anatomy on larger samples.[11,13,17–19] CTA is a preferred method in the detection of visceral injuries and fractures in trauma patients as well as extraluminal pathologies, including aneurysms, because of its short imaging time and thin sections.[17–19]

Considering the current CTA studies in the literature, the incidence of variational branching patterns in the lower extremity and the number of extremities are reported as; 16.4% in 126 extremities by Yanık et al.,[20] 13% in 636 extremities by Çalışır et al.,[21] 11.3% in 1261 extremities by Demirtaş et al.[11] and 10.8% in 1242 extremities by Kil and Jung.[22] In our study, 1500 extremities were examined, and the incidence of the variations in the right leg was found as 5.5% and in the left leg as 4.9%.

Regarding the variations in the branching patterns of the popliteal artery, Kim et al.[10] modified the Lippert system[23] and presented a new classification in branching pattern of the popliteal artery. This classification has 3 main branching pattern categories and three subgroups for each.[10,22] The incidence of the Type I pattern (94.8%) in our study was the most common branching pattern as similar to the current studies in the literature.[8,11,24] Type I–A, which is one of the subgroups of Type I, was observed to

Table 4
Comparison of laterality of the variations in terms of gender.

	Males (n=603)		Females (n=147)		Test statistics	
Subtype	n	%	n	%	X^2	p
Bilateral	544	90.2	141	95.9	4.856	0.032
Unilateral	59	9.8	6	4.1		

be the most common branching pattern and defined as the regular pattern. Type I–C was the least common Type I pattern compared to the others.[8,10,22,25] The results of our study showed that the incidence of Type I–A was 94.2%; Type I–B, 2%; and Type I–C, 0.6%.

High level (proximal) branching of the popliteal artery was noted as Type II. Previous studies report the incidence of the Type II as 1.6%–7.8%.[3,10,20,21,22,26] The results of our study is consistent with the literature and the incidence of the Type II pattern was 2.4%. While Type II–A and Type II–B patterns were reported to be relatively more common, Type II–C was reported less frequently.[8,14,21] The incidence of Type II–C was determined as 0.2% by Day and Orme[8] and Kim et al.,[10] but this pattern was not encountered in our study. Type II–A1 (2.2%) was reported to be the most common branching pattern in its category.[24] In our study, Type II–A1 was the most common pattern which was present in 1.3% of our cases.

The studies done by using different methods report the incidence of Type III branching pattern in a range of 1% to 11.4%.[8,10,14,22,27] Previous CTA studies by Oner and Oner[28] revealed this incidence as 4.1%, Çalışır et al.[21] as 3.6% (Type III–C pattern was not reported) and Yanık et al.[20] as 3.4% (Type II–B and Type III–C pattern was not reported). According to our results, the incidence of Type III branching pattern was 0.13% which actually is the incidence of Type III–A; since Type III–B and Type III–C variation patterns were not encountered.

Yanık et al.[20] revealed the bilateral incidence of Type I–A as 83%. In our study, the bilateral incidence of Type I–A was 90.8%. Oner and Oner[28] reported the rate of bilateral variation in the popliteal artery branching pattern as 5.9% and the rate of unilateral variation as 9.4%. In our study, the rate of bilateral variation was 0.5%, while its distribution was 0.4% for Type I–B and 0.1% for Type II–B; the unilateral variation rate was found to be 8.7%.

In the comparison of the variations in the branching of the popliteal artery among genders, variations in females were reported more than in males.[28] But some other studies suggested that there was no statistically significant difference in terms of genders.[26] The variations in the right leg (p=0.165) and left leg (p=0.701) in terms of gender showed statistically similar distribution in our study as well.

Conclusion

In this study, the branching patterns of the popliteal artery were determined in a large sample. The diversity of branching patterns can be associated with the number of the samples in the studies. We suggest that the detailed anatomical knowledge of the variations in the branching pattern of the popliteal artery (in terms of level and localization of the branching) is crucial for the interventional radiologists and vascular surgeons in evaluation of the vascular supply of the leg to decrease any kind of complications during the vascular interventions.

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Conflict of Interest

The authors declared that they had no conflict of interest.

Author Contributions

NGÇ: project development, data collection, data processing, writing the article; ZF: project development, data collection, editing the article and significant contributions to concept of the study; AKK: data processing, interpretation, editing the article; AN: data collection and interpretation.

Ethics Approval

This study was approved by the Selçuk University School of Medicine Non-Interventional Clinical Research Ethics Committee (approval date and number: 2018/284).

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