Original Article

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Variant Anatomy of Popliteal Vessels- A Cadaveric Study

Anatomy Section

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ABSTRACT

Introduction: The popliteal fossa is a narrow intermuscular space posterior to knee joint. This area is vulnerable during knee arthroplasty or high tibial osteotomy. Therefore, awareness of anatomical variations in the popliteal fossa is important for anatomists, radiologists and surgeons. Popliteal Artery (PA) is frequently affected by penetrating and blunt trauma involving the lower extremity. Therefore, exposure of this artery is often required in both emergency and elective vascular procedures. The Popliteal Vein (PV) is formed at the distal border of popliteus. Pulmonary embolisms originate in deep vein thrombosis in lower extremities. The thrombus forms in the calf veins and subsequently embolize to the lungs. With continued increase of interventional procedures, the anatomical variations in the region of popliteal fossa may have an influence on the success of surgical reconstruction, transluminal angioplasty or embolectomy.

Aim: To study the morphology and variations in popliteal vessels by dissection.

Materials and Methods: The present study was a cadaveric study which was conducted on 30 lower limbs belonging to 15 formalin fixed adult human cadavers. Properly embalmed adult human cadavers were included in the study. Cadavers with any lower limb deformity or with history of surgery in popliteal fossa were excluded from the study. The data was entered in Microsoft excel sheet and expressed in percentage.

Results: According to the classification given by Kim D et al., 96.6% cases were classified as Type IA. Higher bifurcation of PA into posterior tibial and common trunk of anterior tibial and peroneal was described as Type IIB. In addition, the PV was seen to be formed at the lower border of popliteus in 28 specimens (93.33%). Two specimens (6.67%) showed a variable level of formation.

Conclusion: Considering such variable morphology of structures in the popliteal fossa, the surgeons operating around the knee joint should be aware of the possible variations in order to avoid undue complications.

Keywords: Deep vein thrombosis, High tibial osteotomy, Popliteal artery variations, Popliteal vein variations

INTRODUCTION

The popliteal fossa is a narrow intermuscular space posterior to knee joint. When the boundaries of the fossa are separated, its contents are revealed as the popliteal vessels, tibial nerve and its branches, common peroneal nerve and its branches, short saphenous vein, sural nerve, posterior femoral cutaneous nerve, articular branch from obturator nerve, lymph nodes and fat [1]. This area is vulnerable during knee arthroplasty or high tibial osteotomy [2]. Therefore, awareness of anatomical variations in the popliteal fossa is important for anatomists, radiologists and surgeons [3]. The PA is about 20 cm long. It begins at the hiatus in adductor magnus as continuation of femoral artery and ends at the lower border of popliteus muscle (greggor) where it divides into anterior and posterior tibial arteries [4]. It gives genicular branches, superior genicular arteries i.e., superior medial genicular artery (SMGA) and superior lateral genicular artery (SLGA), middle genicular artery (MGA), inferior genicular arteries i.e., inferior medial genicular artery (IMGA) and inferior lateral genicular artery (ILGA), muscular branches, cutaneous branches and sural arteries. The fixity of distal popliteal vessels at the lower angle of popliteal fossa results in frequent injury to these vessels when fractures and dislocations around knee joint occurs. The site of passage of this artery through adductor hiatus is a common area for atherosclerotic stenosis [5].

Morphological variations of PA has been reported to range from 4 to 14.6%. A few classifications have been proposed for these morphological variants [6]. A currently used classification by Kim D et al., divides the branching pattern of PA into three types (I-III), with each type classified further into three subtypes (A-C).

Type I (Normal division)

IA: Normal pattern

IB: Trifurcation

IC: Anterior tibio- fibular trunk

Type II (High division)

IIA: Anterior Tibial Artery (ATA) arises at or above popliteus muscle

IIB: Posterior Tibial Artery (PTA) arises at or above popliteus muscle

IIC: Fibular artery arises at or above popliteus muscle.

Type III (Aplastic/Hypoplastic)

IIIA: Hypoplastic/Aplastic PTA

IIIB: Hypoplastic/Aplastic ATA

IIIC: Hypoplastic/Aplastic PTA and ATA

Popliteal artery is a common receiving site for above and below knee bypass grafts. It is also frequently affected by penetrating and blunt trauma involving the lower extremity. Therefore, exposure of this artery is often required in both emergency and elective vascular procedures [7]. The PV is formed, at the distal border of popliteus, by the union of anterior and posterior tibial veins [6]. It ascends through the popliteal fossa to the opening in adductor magnus where it becomes femoral vein. Its tributaries are short saphenous vein, muscular vein and the veins corresponding to branches of PA. There are usually 4-5 valves in PV [1].

Pulmonary embolisms are thought to originate in deep vein thrombosis in lower extremities. The thrombus forms in the calf veins, propagate into femoro-popliteal system and subsequently embolize to the lungs [8]. The presence of numerous variations among deep vein within the popliteal fossa raises the risk of potential for deep vein thrombosis secondary to changes in flow velocities. This may also amplify the possibility of negative result during deep vein thrombosis diagnostic procedures in cases of a missed thrombus during ultrasonography image analysis [9].

The vascular system is known to display a wide range of anatomical variations. With continued increase of interventional procedures, the anatomical variations in this region may have an influence on the success of surgical reconstruction, transluminal angioplasty or embolectomy [10]. Thus, the present study was done with an aim to study the morphology and variations in popliteal vessels.

MATERIALS AND METHODS

The present study was a cadaveric study, conducted on 30 lower limbs belonging to 15 formalin fixed adult human cadavers which were dissected using Cunningham's Manual for Dissection Volume 1 [4]. The study was conducted over a period of 25 months (September 2012-October 2014). Properly embalmed adult human cadavers were included in the study. Cadavers with any lower limb deformity or with history of surgery in popliteal fossa were excluded from the study. Study was conducted after obtaining approval from the Institutional Ethical Committee (Ref. CMC/3505).

STATISTICAL ANALYSIS

The data was entered in Microsoft excel sheet and expressed in count (percentage).

RESULTS

PA, its branching pattern and level of termination was studied. Following observations were made in the genicular branches of PA:

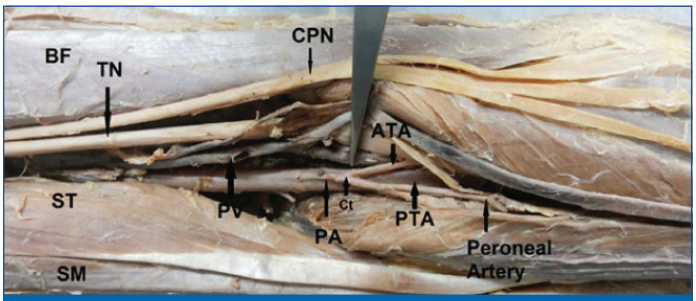
a. In one limb (3.33%), the IMGA originated at the level of femoral condyles. The remaining 96.67% showed a typical pattern for IMGA.

b. The ILGA originated at the level of femoral condyles in two specimens (6.67%).

c. In all 30 limbs the MGA was given off in the center of fossa. However, the MGA was seen to be arising from a common trunk with SMGA and with SLGA in two cases.

d. Double MGA was seen in one specimen.

According to the classification given by Kim D et al., 96.7% cases were classified as Type IA. Higher bifurcation of PA into posterior tibial and common trunk of anterior tibial and peroneal as Type IIB was seen in 1 case (3.3%), Type II A was also seen in the same case [Table/Fig-1].

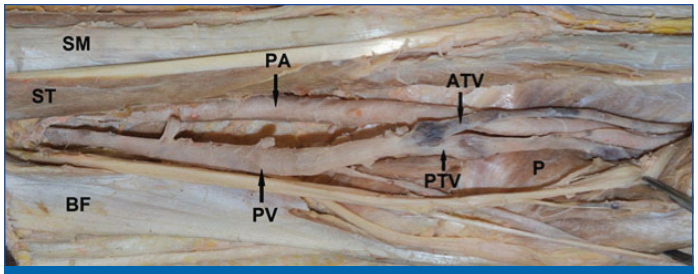


[Table/Fig-1]: Showing high termination of popliteal artery.
SM: Semimembranosus; PA: Popliteal artery; ST: Semitendinosus; PV: Popliteal vein; BF: Biceps femoris; TN: Tibial nerve; CPN: Common peroneal nerve; ATA: Anterior tibial artery; PTA: Posterior tibial artery; Ct: Common trunk

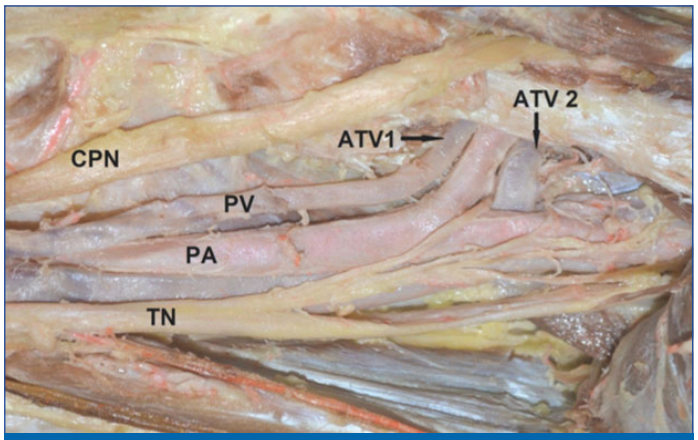
In the present study, the PV was seen to be formed at the lower border of popliteus in 28 specimens (93.33%). Two specimens (6.67%) showed a variable level of formation. The anterior and the posterior tibial veins united at the level of tibial condyle in one specimen as seen in [Table/Fig-2]. In one case, double anterior tibial vein was seen to be present [Table/Fig-3]. The proximally placed anterior tibial vein joined the posterior tibial vein at the level of tibial condyles and the distally placed anterior tibial vein joined the posterior tibial vein at the lower border of popliteus muscle.

DISCUSSION

In the embryo before 14 mm stage the axis artery of lower limb is the arteria ischiadica. At the level of knee joint the axis artery



[Table/Fig-2]: Showing higher level of formation of popliteal vein.
SM: Semimembranosus; PA: Popliteal artery; ST: Semitendinosus; PV: Popliteal vein; BF: Biceps femoris; P: Popliteus; ATV: Anterior tibial vein; PTV: Posterior tibial vein



[Table/Fig-3]: Showing double anterior tibial veins.
CPN: Common peroneal nerve; PA: Popliteal artery; TN: Tibial nerve; PV: Popliteal vein; ATV: Anterior tibial vein

becomes popliteal. At 14 mm stage the arteria ischiadica is being supplemented by the femoral artery. The longitudinal arteries which traverse the leg in the embryo, the future posterior tibial and peroneal arteries, arise from the axial vessels at the upper border of popliteus muscle. A gradual proximodistal union of posterior tibial and peroneal artery occurs. This union forms the part of definite PA that lies behind popliteus muscle. A communicating branch from the lower border of popliteus enlarges to become definite anterior tibial artery [11].

Literature was reviewed to observe the variations in the PA branching pattern as studied by several authors and was compared to the findings of present study [Table/Fig-4]. Popliteal artery variations are not rare [6,10]. It has been reported to vary from 0.4-12% [12-21]. The three most frequently encountered variations, following the usual patterns are: Type III A, Type II A and Type I B [20]. It is important to recognise anatomical variations for planning radiological and surgical intervention, particularly when rare Type III infra popliteal patterns are present. It may be necessary to modify the angioplasty technique to take in account absence of vessels to minimise complications [16]. In addition, harvesting of PA for free flap transfer procedure is contraindicated if Type III pattern is present. Because PA is the only artery that supplies the distal part of lower limb in Type IIIC branching pattern, this procedure could result in ischemia of foot [22].

Arteriographic studies have revealed that the most common vascular abnormality associated with clubfoot has been absent ATA, reported in 85% of children with clubfoot. Therefore, variations involving this vessel are of particular concern when these patients are managed surgically [18].

The present study was in concordance with studies done by Adachi B [13] and Trotter M [14] in having over 90% Type IA branching pattern. In an analysis done by Tomaszewski KA et al, it was observed that Asian studies differed in type III analysis with a prevalence of 5.9% compared with prevalence rates of 2.0% and 3.3% in North Americans and Europeans, respectively. More specifically, Asians presented with a type III-B (hypoplasia or aplasia

Author	Type of study	Number of lower limbs	Type I A	Type I B	Type I C	Type II A1	Type II A2	Type II B	Type II C	Type III A	Type III B	Type III C
Quain R [12]	Cadaveric	258	90.3	6.6	2.3	0.8	-	-	-	-	-	-
Adachi B [13]	Cadaveric	770	96	0.5	0.8	0.9	1	0.8	-	-	-	-
Trotter M [14]	Cadaveric	1168	93.4	1.3	0.5	1.5	2.4	1.4	-	-	-	-
Keen JA [15]	Cadaveric	280	90.7	0.4	4.3	3.6	0.4	1.1	-	-	-	-
Day CP and Orme R [16]	Angiogram	1037	90	3.2	0.3	2.1	-	1.1	0.2	0.8	0.1	0.1
Mavili E [3]	DSA	535	82.4	5.4	0.4	2.6	-	1.5	-	3.7	2.2	0.2
Ozgur Z [17]	Cadaveric	40	90	-	2.5	5	-	2.5	-	-	-	-
Alsharawy S [18]	Cadaveric	40	90	2.5	-	-	-	-	-	2.5	-	-
Oztekin PS [19]	CT Angiography	495	87.5	3	1.2	1.4	0.4	1	-	3.3	0.6	0.4
Demirtas H [20]	CT Angiography	1261	88.7	2.5	0.6	2.2	0.4	0.6	-	-	2.2	0.1
Kim D et al., [6]	Angiography	605	92.6	1.2	2	3	0.7	0.8	<0.2	-	-	-
Olewnik L [21]	Cadaveric	80	72	12	8	-	-	-	-	8	1.2	0.1
Present Study	Cadaveric	30	96.7			3.3						

[Table/Fig-4]: Showing incidence of variations in popliteal artery in literature (%) [3,6,12-21].

of the AT) prevalence of 4.1% compared with 1% and 0.7% in North America and Europe, respectively. This reflects the findings in a previous study performed was only on the Japanese population, in which the only type III variation seen was of the type III-B variety. There was a lack of any other significant geographic differences or study modality (imaging or cadaveric) differences [23]. In the literature, gender-based comparisons are limited and no significant differences between the variation rates in females and males were reported in previous studies [24]. However, in a study conducted by Oner S and Oner Z, PA branching variations were about twice as frequent in females when compared to males (23%, 11.9%) [25]. Variations in lower limb venous anatomy are common and have important implications for diagnosis of conditions like deep vein thrombosis [26].

In a 9-week-old embryo, deep veins appear in form of and endothelialised vascular lacuna surrounding the arteries. The three networks- superficial primary postaxial, superficial secondary preaxial and deep ones- prefigure globally and respectively the short saphenous vein, the long saphenous vein and femoral vein and the deep popliteal and femoral veins. With time, anastomosis occurs between the superficial pre and postaxial and deep axial networks. The first anastomosis establishes a connection between the axial plexus below knee level with the preaxial plexus above knee level. This anastomosis generates the popliteal vein that drains all the deep leg axis to the thigh axial plexus [27].

Variations in anatomy of lower extremity venous system have been studied with use of cadavers venography and duplex ultrasound. These studies have shown different results depending on the study population and the modalities used [28].

The varied results of variation in formation of PV has been tabulated in [Table/Fig-5] [8,9,26,28-30].

Author and publication Year	Type of study	Number of cases	Findings	
			High level of formation	Duplication
Sadowska A et al.,2013 [9]	Cadaveric	64	18.17%	7.8%
Quinlan DJ et al.,2003 [26]	Venography	808	-	5%
Trigaux JP et al.,1991 [29]	Cadavers	12	-	7%
	CT scan	40		
	X-Ray	30		
Simpson WL and Krakowski DM, 2010 [8]	Duplex ultrasound	2664	-	10%
Park EH et al., 2011 [28]	CT venography	1890	83%	2% showed multiplication pattern 10% showed complex networks
Dona E et al., 2000 [30]	Duplex ultrasound	248	-	18%
Present study, 2021	Cadaveric	30	6.67%	-

[Table/Fig-5]: Showing comparison of variations in the level of formation of popliteal vein [8,9,26,28-30].

The present study is not in concordance with the above mentioned studies. There is a wide range of variation in level of formation of PV. There is as high incidence of a higher level of popliteal vein formation as 83% [28] and as low as 18.1% [9]. However, the incidence of duplication of popliteal vein has been reported to range between 2-18% [23-25]. Veins serve as the best material for arterial grafting and therefore understanding deep and superficial veins is very important. Upto 73% of women and 53% men worldwide are diagnosed with Chronic Venous Insufficiency (CVI). The significance of lower limb venous anatomy was determined in line with the development of minimally invasive surgical interventions methods for CVI (laser, foam, subendothelial and thermal coagulation methods). The understanding of normal and variant anatomy is important to prevent complications during intervention [31].

Limitation(s)

The main limitation of present study was the small sample size. The work is based only on dissection; it's findings should be complimented by data from angiographic studies to make it clinically more significant. Also, since the number of male and female cadavers were not equal, comparison of the findings could not be done amongst both genders.

CONCLUSION(S)

Popliteal fossa is a region of interest to surgeons, radiologists and orthopaedic surgeons. Considering such variable morphology of popliteal vessels, a thorough knowledge of variant anatomy in this area is essential to plan procedures and avoid undue complications, therefore ensuring better patient outcome.

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