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Original Research Article

ANATOMICAL VARIATIONS AND MORPHOMETRIC ANALYSIS OF POPLITEAL ARTERY AND ITS TERMINAL BRANCHES IN SOUTH INDIAN POPULATION

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ABSTRACT

Introduction: Popliteal artery which is the continuation of femoral artery at the adductor hiatus, gives off its terminal branches, anterior tibial artery and posterior tibial artery. Anterior tibial artery attracts clinical significance since it is vulnerable at the fibular neck during tibial osteotomy. Posterior tibial artery, felt behind the medial malleolus is utilized for arteriovenous shunt with great saphenous vein during hemodialysis and attains clinical significance. Injury to the popliteal artery causes ischemia and it warrants immediate surgical intervention to prevent compartment syndrome. Peroneal artery takes part in crural collateral circulation and this peroneal bypass is of great significance and can be utilized by vascular surgeons.

Materials and Methods: Popliteal artery and its terminal branches, anterior tibial artery, posterior tibial artery, and peroneal artery were dissected out in fifty random lower limbs, made available from the dissection hall. The variations in their branching pattern, the lengths of popliteal artery from adductor hiatus to its bifurcation, its length up to femoral condyles, the length of tibioperoneal trunk, the diameters of popliteal artery, tibioperoneal trunk, anterior tibial artery, posterior tibial artery and peroneal artery were measured.

Results and Conclusion: The dimensions from this study done in South Indian population were compared with similar studies across the world, like German, American, British, Africans, Turks, Japanese and Thai. This analyzed data is likely to be useful in therapeutic and interventional procedures like arterial reconstruction in femoro-popliteal bypass graft, in surgeries performed around knee joint, for infra popliteal interventions as in bypass surgery.

KEY WORDS: Popliteal artery, Popliteal fossa, Tibioperoneal trunk, Anterior tibial artery, Posterior tibial artery, Peroneal artery, Tibial osteotomy, Arteriovenous shunt, Hemodialysis, Femoro-popliteal bypass graft, peroneal bypass.

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INTRODUCTION

The popliteal artery is the continuation of femoral artery at the adductor hiatus [1]. Throughout the course, it is the deepest of the neurovascular structures in the popliteal fossa [2]. The artery supplies the popliteal region and the knee joint through its direct branches and contributes to the effective anastomosis around the knee joint [3]. The popliteal artery could be a continuation not of femoral artery, but of the sciatic artery

(a branch of inferior gluteal artery). When this occurs, the popliteal artery has an abnormal relationship to popliteus [2].

The anterior tibial artery on occasions, is small but is rarely absent and its function is replaced by perforating branches from posterior tibial artery or peroneal artery [4]. Sometimes it is larger than normal, and therefore its territory of supply in the foot may be increased to include the plantar surface also. When the posterior tibial artery is reduced in length or in calibre, the peroneal artery takes over its distal territory of supply and may be consequently increased in size [5]. The size of the peroneal artery is usually inversely related to the size of anterior and posterior tibial arteries. The peroneal artery gains greater significance in formation of natural crural collateral circulation and this peroneal bypass can be utilized by vascular surgeons [6].

Variations in the terminal branches of popliteal artery are of 3 types. Type I has normal level of popliteal arterial branching pattern, and this once again has 3 subtypes A, B &C. Type I A has the usual pattern where the anterior tibial artery is the 1st arterial branch, posterior tibioperoneal trunk follows and further bifurcates into posterior tibial and peroneal artery. Type I B is the trifurcation pattern and is seen where the anterior tibial, peroneal and posterior tibial artery arise within 0.5cm and there is no tibioperoneal trunk. Type I C is anterior tibioperoneal trunk pattern where the posterior tibial artery is the 1st branch, anterior tibioperoneal trunk follows and bifurcates into anterior tibial artery and peroneal artery.

Type 2 has high division of popliteal artery and has 3 subtypes namely A, B & C. In Type 2 A the anterior tibial artery arises at or above the knee joint. This in turn has A1 and A2 patterns. In type 2 A1 variety the anterior tibial artery is the 1st branch and it arises above knee and has normal course posterior to popliteus muscle. In type 2 A2 variety, the anterior tibial artery arises above knee and has medial course anterior to popliteus muscle. In Type 2 B the posterior tibial artery arises at or above knee joint. The posterior tibial artery is the 1st branch which arises above knee joint and has a common trunk for anterior tibial and peroneal arteries. In type 2C the peroneal artery which is the first branch arises at or above knee joint and next has common trunk for anterior tibial artery and posterior tibial artery.

In Type 3 the branches are hypoplastic/aplastic with altered distal supply. Type 3 has 3 subtypes namely A, B and C. In Type 3 A the posterior tibial artery is hypoplastic/aplastic. Here the peroneal artery is large. The distal posterior tibial artery is replaced by peroneal artery. In Type 3 B the anterior tibial artery is hypoplastic/ aplastic and the peroneal artery is large. Distally the dorsalis pedis artery is replaced by peroneal artery. In Type 3 C both the anterior tibial artery and posterior tibial artery are hypoplastic/aplastic. Here both the dorsalis pedis artery and posterior tibial artery are replaced by peroneal artery.

Popliteal artery may sustain intimal injury, avulsion, occlusion, aneurysm formation, embolus formation and rupture of thrombus. If the extent of injury causes flow interruption in the popliteal artery, patients may complain of pain, paresthesia or loss of sensation and motor dysfunction distal to knee joint. Limb ischemia more than 4-6 hours can cause irreversible neurologic damage, muscle necrosis and can lead to adverse outcomes including limb loss. Surgical management includes fasciotomies, to treat and prevent compartment syndromes [7], surgical revascularization using bypass grafts with saphenous vein graft to resume recirculation. A knowledge of the development of the popliteal artery provides a better understanding of the atherosclerotic popliteal artery aneurysms and the popliteal artery entrapment syndrome [8]. The diameter of arteries are the most important determinants of the patency in femoro-popliteal and femoro-tibial grafts and peroneal bypass procedures [6]. The present study is focused on the anatomical variations in popliteal artery, its terminal branching pattern, morphometric analysis of the popliteal artery and its branches.

MATERIALS AND METHODS

This study was conducted in 50 right and left side lower limb specimens belonging to the southern part of India, without any specification to age and sex. These specimens were serially numbered. Routine dissection instruments,

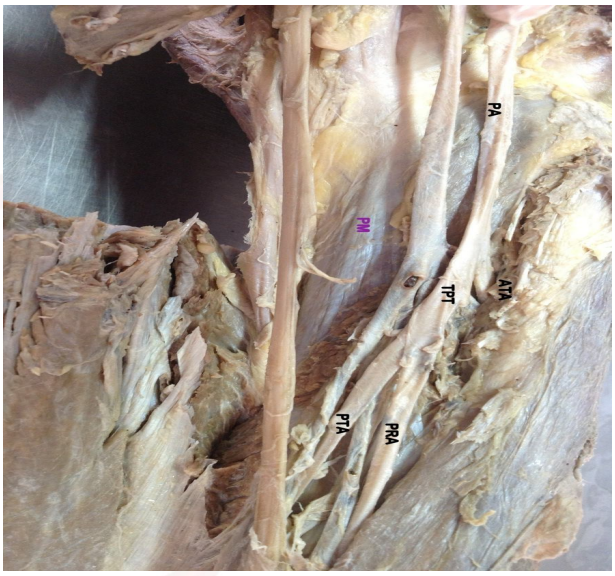
vernier calipers, thread and scale were used for this study. The popliteal fossa was dissected by reflecting the skin, the cutaneous structures, the deep fascia and identifying the boundaries of the popliteal fossa. The popliteal vessels and tibial nerve were exposed. The terminal branches of the popliteal artery, the anterior tibial, posterior tibial arteries and its branch, the peroneal artery were identified and traced along the back of fibula, undercover of flexor hallucis longus. The following parameters were observed in the specimens. (1) The variations in terminal branching patterns of popliteal arteries were noted and photographed for documentation (2) The length of the popliteal artery from adductor hiatus to bifurcation point (3) Length of popliteal artery from adductor hiatus to femoral condyles(4) Length of tibioperoneal trunk were measured using thread and scale(5) The diameter of popliteal artery at the level of 5 cm distal to adductor hiatus (6) diameter of tibioperoneal trunk (7) diameter of anterior tibial artery (8) diameter of posterior tibial artery and (9) diameter of peroneal artery were measured using vernier calipers in the present study.

RESULTS

In the present study, Type I A was seen in 45 specimens (Fig: 1) out of the total 50 i.e., 90%. Type I B pattern was seen in 2 specimens i.e., 4%. Type I C pattern was seen in 1 specimen i.e., 2%. Type 2 A1, Type 2 A2 was not observed in any specimen. Type 2 B was seen in 1 specimen i.e., 2% and Type 2C, was observed in 1 specimen i.e., 2%. Type 3A, 3B, 3C pattern was not observed in any specimen, in the present study.

The length of popliteal artery and its terminal branches were measured. L1 is the length of the popliteal artery from the adductor hiatus to the bifurcation point and it ranged between 126.5 to 188.8 mm and had a mean value of 151.5mm. There were 28 specimens (56%) which measured between 126-150mm, 18 specimens (36%) had their lengths between 151-175mm and 4 specimens (8%) measured between 176-200mm. L2 is the length of the popliteal artery from the adductor hiatus to femoral condyles which ranged between 131.7 to 144mm and had a mean value of 136.5mm. There were 20 specimens (40%) which had their length between 130-135mm, 28 specimens (56%) measured between 136-140mm and 2 specimens (4%) measured between 141-145mm. L3 is the length of tibioperoneal trunk, it ranged from 0.3 to 4.3mm and had a mean value of 3.4mm. A total of 37 specimens (74%) measured >3cm, 8 specimens (16%) measured between 2-3cm and 5 specimens (10%) measured <2cm.

Fig. 1: Specimen showing all the five arteries-PA (popliteal artery), TPT (Tibioperoneal trunk), ATA (Anterior tibial artery), PTA (Posterior Tibial artery), PRA (peroneal artery) and PM (Popliteus Muscle).



The diameter of the arteries was measured. The diameter D1 of popliteal artery at the level of 5cm distal to adductor hiatus ranged from 6.3mm to 8.4mm and had a mean value of 7.36mm. There were 9 specimens (18%) that measured in 6-7mm range, 39 specimens (78%) in 7-8mm range and 2 specimens (4%) in 8-9mm range. The diameter D2 of tibioperoneal trunk ranged from 4.1mm to 6.8mm with mean value of 4.88mm. Out of the 50 specimens studied, 35 (70%) were in the range of 4-5mm, 13 (26%) were in the range of 5-6mm and 2 specimens (4%) were in the range of 6-7mm. The diameter D3 of anterior tibial artery ranged from 2.1mm to 4.4mm, and had a mean value of 3.128mm. In 19 specimens (38%) the diameter was in the range of 2-3mm, 27 (54%) were in the range of 3-4mm and 4 (8%) in the range of 4-5mm. The diameter D4 of posterior tibial artery ranged from 3.3mm to 5.6mm and had a mean value of 4.214mm. Of the 50 specimens, 20 (40%) measured between 3-4mm, 25(50%) between 4-5mm and 5(10%) measured between 5-6mm.

The diameter D5 of peroneal artery ranged from 3.1mm to 5.2mm and had a mean value of 3.964mm. There were 27 specimens (54%) which measured between 3-4mm, 21 (42%) measured between 4-5mm and 2 (4%) between 5-6mm.

Table 1: Number and frequency of variations in terminal branching patterns of popliteal artery in the present study.

Branching type	No of limbs	Percentage (%)
Type 1 A	45	90
Type 1 B	2	4
Type 1 C	1	2
Type 2 A1	0	0
Type 2 A2	0	0
Type 2 B	1	2
Type 2C	1	2
Type 2D	0	0
Type 3A	0	0
Type 3B	0	0
Type 3C	0	0

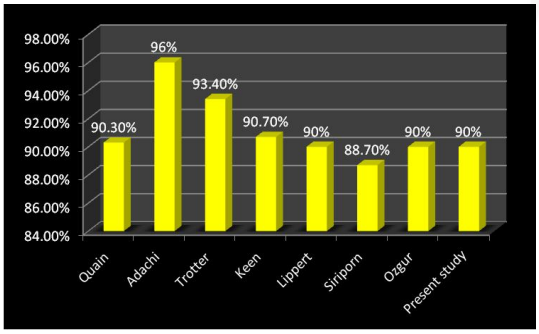
Table 2: Comparative table of lengths of popliteal artery from adductor hiatus to the bifurcation point (L1), popliteal artery from adductor hiatus to femoral condyles (L2) and tibioperoneal trunk (L3) from different studies.

Parameters	References			
	Ozgur Turkish	Selda Turkish	Kim American	Present South Indian
L1	191.1±34.7mm	126.82mm	-	151.46mm
L2	138.1±23.8mm	-	-	136.46mm
L3	30.3±16.2mm	-	3.9cm	3.53cm

Table 3: Diameters of popliteal artery (D1), tibioperoneal trunk (D2), anterior tibial artery(D3), posterior tibial artery(D4), peroneal artery (D5) from different studies.

Parameters	References				
	Ozgur Turkish	Selda Turkish	Heise Germany	Maria Bulgaria	Present study South India
D1	8.2±1.6mm	8.3mm	-	-	7.4mm
D2	5.2±1.1mm	-	-	-	4.9mm
D3	6.1±1.1mm	3.15mm	0.27±0.02mm	1.5mm	3.1mm
D4	4.5±0.9mm	3.44mm	-	4.2mm	4.2mm
D5	4.4±0.9mm	4.44mm	-	-	3.96mm

Graph 1: Comparison of frequency of Type I A branching pattern seen in different studies.



DISCUSSION

Variations in terminal branching patterns of popliteal artery noted in our series are similar to the studies conducted in the Turkish [9], Germans [10], British [11], Americans [12], Thai [13], Africans [14] and Japanese [15] population. Our observations (Table 1) have concurred with the reports of earlier workers (Graph 1) who have reported that majority (around 90%) of the specimens showed Type I A normal branching (Fig.1). The trifurcation branching pattern of popliteal artery Type I B, seen in South Indian population (4%) was similar to the Germans and Americans. Similar pattern was also seen in the Turks, British, Japanese, African and Thai. Type I C pattern of branching was seen in 2% specimens in the present study and this was close to the statistics of African population studied. High division of popliteal artery above knee joint identified as Type 2 A1 [16,17] and the anterior tibial artery lying posterior to the popliteus muscle reported in the population across the world with varying incidence was absent in the South Indian population currently studied. Type 2 A2 pattern of high division of popliteal artery and the anterior tibial artery branch lying anterior to popliteus muscle was not seen in the South Indian study which compared well with the British [11] and Turkish [9] population studied. In the present study, type 2B, with high division of popliteal artery and posterior tibial artery arising as the first branch above knee joint was seen in 2% specimens and this correlates with study done in the Turkish population. This pattern reported in the Africans, Americans, German, Thai and Japanese with an incidence of around 1% has not been reported in the British study. Type 2 C pattern where peroneal artery arises at or above knee joint and then a common trunk for anterior and posterior tibial artery arises was seen in 2% specimens in our present study. This type of branching pattern has not been reported in the British, Japanese, Africans, Americans, German, Thai and in the Turkish population.

Type 3A pattern with hypoplastic/aplastic posterior tibial artery and enlarged peroneal artery has not been observed in any study across the world or in the present study as well. Type 3B with hypoplastic/aplastic anterior tibial artery

and enlarged peroneal artery has not been observed in the present study which correlates with the British, African and Turkish study. It has been reported by the Japanese 7.1%, German 6%, American 5%, and Thai 3% studies. In this 3B pattern the distal dorsalis pedis artery is replaced by peroneal artery [5].

The Type 3C pattern in which both anterior and posterior tibial arteries are hypoplastic/aplastic and the peroneal artery is enlarged. This was not reported by other studies across the world including the present South Indian population. The I A pattern of branching was the commonest pattern seen in this study as also reported across the world. The 3A and 3C hypoplastic vessel pattern was not reported in the present study and this correlates with most of the studies across the world. The IA, 2A2, 2B, 3B pattern of branching in the South Indian population correlated with the Turkish study. The 2A2, 3B pattern of branching seen in South Indian population is similar to the British study. The I C, 3 B pattern of branching in South Indian population was similar to the pattern observed in the African population. The I B pattern seen in South Indians is similar to patterns observed in Germans and Americans.

In our study, length of popliteal artery from the adductor hiatus to the bifurcation point L1 was found to be lesser than in the Turkish population as reported by Ozgur et al [9], but greater than in Turkish study as reported by Selda et al [16], refer Table 2. However, length of the popliteal artery from adductor hiatus to femoral condyles (L2) in our study, more or less was in agreement with the observations of Ozgur et al from Turkey. In the present study, the mean length of tibioperoneal trunk L3 was less than the value reported in the American study [18] but relatively more than the Turkish [9] study.

Diameters of both the popliteal artery D1 and tibioperoneal trunk D2 in the present study were found to be lesser than these measurements from the Turkish population as reported by Ozgur. Z et al [9], refer Table 3**.** The diameter of anterior tibial artery (D3) in the present series was compared with the data available from Turkey [9,16], German [19] and Bulgaria [20]. It correlated with the Turkish study by Selda et al. The mean diameter of posterior tibial artery (D4) in our series was compared well with the data from Bulgaria [20] while the diameter of peroneal artery (D5) was, a little lower than the data from Turkey [9,16].

The foregoing account establishes the fact that the blood vessels of the lower limb, in general and the leg arteries, in particular, can present variable morphology and morphometry, and stand out vividly from such patterns of these arteries seen in other population. This fact, by itself, provides us enough reasons to document such variations.

This study can contribute immensely towards the better understanding of vascular anatomy of the lower limb, which can be of help to the vascular surgeons during arterial reconstruction in femoro-popliteal bypass graft procedure, orthopedic surgeons to prevent vascular injuries while performing surgeries around knee joint, interventional radiologists for the safe performance of infra popliteal interventions such as bypass surgery, transluminal angioplasty and subintimal angioplasty.

CONCLUSION

In the present cadaveric study Type 1A, Type 1B and Type 1C branching pattern of popliteal artery were observed with Type 1A branching pattern seen in maximum specimens. Type 2B and Type 2C were also observed in this study. Type 2A1, Type 2A2, Type 3A, Type 3B and Type 3C were not observed in the present study.

The length of popliteal artery (L1) in the present study had a significantly different value from Turkish studies. Length of popliteal artery till the level of femoral condyle (L2) was less compared to Turkish population considered for comparison. However, length of tibioperoneal trunk (L3) in the present study was more compared to the Turkish population, studied.

Popliteal artery (D1), tibioperoneal trunk (D2), posterior tibial artery (D4) and peroneal artery (D5) in the present study had significantly smaller diameters as compared to the diameters recorded in the Turkish studies. The diameter of anterior tibial artery (D3) was similar to the study done in Turkey.

These variations can give an insight to the surgeons in interventions for popliteal artery aneurysm, knee joint surgery including total knee

arthroplasty, in surgery for fractures involving the distal end of femur, proximal end of tibia and fibula.

As a result of globalization, there has been constant migration of people, and with increase in medical tourism patients move across the borders of the country to get treated. It has become important for the operating surgeon to be aware of the anatomical variations encountered in different populations. The present study in the South Indian population shows many similarities with the Turkish population. The radiologist, vascular surgeon, orthopedician would find this data informative and useful in performing therapeutic and interventional procedures at this arterial site.

The results of this study, will have a better significance when it is compared with the intraluminal diameter in contrast enhanced Computed Tomography images. In future to bear more relevance, similar study would be done to include this aspect as well.

Conflicts of Interests: None

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