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Original Research Article

CADAVERIC STUDY ON ANATOMICAL VARIATIONS OF POPLITEAL ARTERY AND ITS TERMINAL BRANCHES: A CLINICAL PERSPECTIVE

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ABSTRACT

Introduction: Anatomical knowledge is very important for accurate diagnosis and proper treatment of the patient. The popliteal region presents a wide range of vascular anomalies. The correct diagnosis of these anatomical variations plays a key role in success of diverse procedures performed by orthopaedicians, vascular surgeons and radiologists. In this context, the aim of our study was to gain knowledge on the origin, level and mode of termination, course and relations of popliteal artery with surrounding structures, mainly the muscles, in popliteal fossa. The results obtained were compared with previous studies.

Materials and methods: The study was carried out in 50 lower limbs of 25 well-embalmed cadavers. There was no evidence of previous knee surgeries in any of the limbs. The specimens were collected from the department of Anatomy, KVG Medical College, Sullia.

Results: The femoral artery continued as popliteal artery, which terminated at the lower border of popliteus muscle. Trifurcation pattern was observed in one specimen. 10% of specimens had hypoplastic/aplastic posteriortibial artery, distally replaced by peroneal artery. Another 4% of specimens had smaller posterior tibial and larger peroneal artery. Length of tibio peroneal trunk from the lower border of popliteus muscle was shorter than normal (2.5 cm) in one specimen and longer in another specimen. The observation on course and relations showed that the popliteal artery passed beneath a bony tunnel of fibula before terminating in one specimen and in another specimen, popliteal artery was superficial to popliteal vein in the middle of popliteal fossa. In other two specimens, it coursed more medially towards medial head of gastrocnemius and another specimen presented with popliteal artery crossed by muscle belly of plantaris.

Conclusion: This study adds up to the knowledge on vascular variations in the popliteal region, the awareness of which is important to vascular surgeons while performing arterial reconstructions in femoro distal bypass graft procedures and also to orthopaedicians during surgical clubfoot release.

KEY WORDS: Popliteal artery, popliteal vein, popliteus muscle, posterior tibial artery, peroneal artery, trifurcation, medial head of gastrocnemius, plantaris.

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INTRODUCTION

The popliteal fossa is a diamond – shaped depression at the posterior aspect of knee that is bordered by semitendinosus and semimembranosus superomedially, biceps femoris tendon superolaterally, and, medial and lateral heads of gastrocnemius muscle inferiorly. Popliteal artery courses between the medial and lateral heads of gastrocnemius as the continuation of femoral artery. It descends laterally from opening of adductor magnus to femoral intercondylar fossa, inclining obliquely to distal border of popliteus, where it bifurcates into anterior and posterior tibial arteries. Peroneal artery arises from posterior tibial artery approximately 2.5 cm distal to inferior border of popliteus. If peroneal artery branch is high from posterior tibial artery or from popliteal artery separately, the branching pattern is said to be "trifurcation". Based on the level of termination of popliteal artery with respect to popliteus muscle it is considered as "high" – division at its upper border and "low" – division at its lower border. In the upper part of popliteal fossa, popliteal vein and tibial nerve are posterolateral to the artery then they cross the artery and become superficial to it. In the lower part, both are medial to the artery. Popliteal artery is relatively tethered at the hiatus in the adductor magnus, and distally by fascia related to soleus, where it is susceptible to traction damage in knee injuries e.g. – dislocation [1].

Popliteal artery entrapment syndrome is an anomalous relationship between the popliteal artery and its surrounding musculotendinous structures. In 1879, TP Anderson Stuart, an Edinburgh medical student, described this anatomical variant of popliteal artery, which he had dissected from a gangrenous limb [2].

Knowledge of congenital anatomic variations of popliteal vascular branching is mandatory in surgical procedures and radiological diagnosis. In this context, Kim et al [3] classified the popliteal vascular branching patterns into the following categories:

Type 1A: Normal level of bifurcation of the popliteal artery (below knee), with a tibio peroneal trunk length of more than 0.5 cm; the anterior tibial artery is the first branch, and a tibio peroneal trunk follows up to the bifurcation into posterior tibial artery and peroneal artery. This is the usual pattern.

Type 1B: Normal level of bifurcation of the popliteal artery (below knee), with a tibio peroneal trunk length of less than, or equal to 0.5 cm which is "Trifurcation".

Type 1C: Normal level of bifurcation of the popliteal artery (below knee), the posterior tibial artery is the first branch and there is anterior tibio peroneal trunk.

Type 2A: High bifurcation of popliteal artery (above the knee), the anterior tibial artery is the first branch and courses posterior to popliteus muscle (Type 2A -1) or anterior to it (Type 2A-2).

Type 2B: High bifurcation of popliteal artery (above knee), the posterior tibial artery is the first branch and arises at or above the knee joint. Type 2C: High bifurcation of the popliteal artery (above knee), the peroneal artery is the first branch, and arises at or above the knee joint.

Type 3A: Hypoplastic or absent posterior tibial artery, distally replaced by peroneal artery.

Type3B: Hypoplastic or absent anterior tibial artery, distally replaced by peroneal artery.

Type 3C: Hypoplastic or absent anterior tibial and posterior tibial artery, both distally replaced by peroneal artery.

Compensatory hypertrophy of the peroneal artery with a hypoplastic or aplastic posterior tibial artery or anterior tibial artery may indicate variant arterial supply to the foot. This enlarged peroneal artery "peronea magna" or "great" peroneal artery either joins and reinforces the posterior tibial artery or replaces it in the distal leg, and the lower end of it is typically continued into the sole as the lateral plantar artery, the medial plantar artery is usually absent [4].

Awareness on variations of popliteal artery and its branching pattern is important because it has clinical implications during transluminal angioplasty, vascular grafting, direct surgical repair or embolectomy. The sound knowledge of variant arteries also helps in preventing arterial complications like transection, fistula formation, pseudo aneurysms and thrombosis.

With this perspective, the present study was undertaken, wherein popliteal artery and its branching pattern were studied, which serve as a guideline for orthopaedicians, vascular surgeons and radiologists.

MATERIALS AND METHODS

Anatomical variations in popliteal artery branching pattern were looked for in 50 lower limbs of 25 well-embalmed cadavers in the department of Anatomy, KVG Medical College, Sullia, Dakshina Kannada. The lower limbs with previous knee surgeries were not included in the present study. The specimens were dissected according to Cunningham's manual of practical anatomy (vol-1) [5]).The popliteal fossa was approached and the popliteal pad of fat was removed. The tibial nerve, common peroneal nerve and popliteal vein were identified and were separated from the popliteal artery. The popliteal artery was traced upto its terminal branches.

The following parameters were observed, noted and photographed.

The data were compiled and the observations were compared with previous standard observations.

A. Origin

B. Level and mode of termination

C. Course and relations of popliteal artery

RESULTS

1. Origin of popliteal artery: In all the 50 specimens studied, we observed that the popliteal artery was the continuation of femoral artery from the 5th osseoaponeurotic opening of adductor magnus.

2. Level and mode of termination

Level of termination of the popliteal artery: The level of termination of popliteal artery in relation to popliteus muscle was observed. In all the 50 specimens, the popliteal artery terminated at the lower border of popliteus muscle.

Mode of termination: The terminal branches of popliteal artery presented with variations and the mode of termination of popliteal artery was classified according to the system used by Kim et al [3].

Type 1A: Level of bifurcation of popliteal artery below knee. Anterior tibial is the first branch, tibio peroneal trunk length of more than 0.5 cm and it bifurcates into posterior tibial artery and peroneal artery. This is the normal pattern.

Type 1B: Tibio peroneal trunk length less than or equal to 0.5 cm which is "Trifurcation" pattern. *In one specimen there was trifurcation of popliteal artery. Tibio peroneal trunk was 0.5 cm in length.*

Type 2: High bifurcation of popliteal artery above knee. In all the 50 specimens, the terminal branches were at the lower border of popliteus muscle. None of them had high bifurcation.

Type 3: Hypoplastic/ absence of one of the terminal branches.

Type 3A: Hypoplastic or absent posterior tibial artery distally replaced by peroneal artery. *In two cadavers, bilaterally there was complete absence of posterior tibial artery distally replaced by peroneal artery and one cadaver presented unilaterally with hypoplastic posterior tibial artery, distally replaced by peroneal artery. In total, 10% of specimens presented with type 3A variety*.

In two specimens, the posterior tibial artery was smaller and peroneal artery was larger.

Length of tibio peroneal trunk: The normal length of tibio peroneal trunk is around 2.5cm. * Length in one specimen was shorter, around 1.4 cm, and in the other specimen it was longer, around 5.25 cm.*

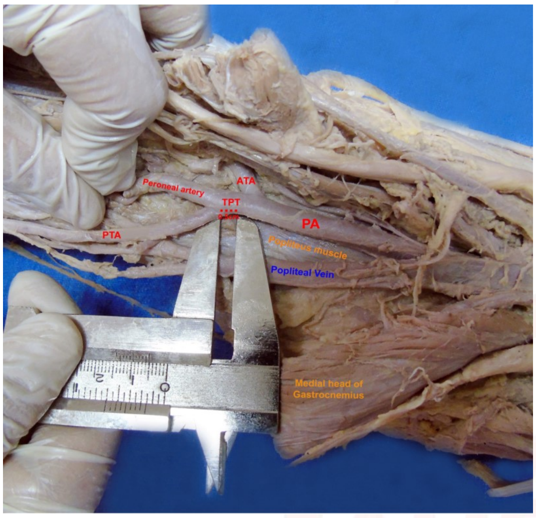
Course and relations of popliteal artery: In one specimen popliteal artery after crossing the lower border of popliteus muscle, inclining laterally ,enters beneath a bony process, which was extending from medial half of upper one third of posterior surface of fibula, which had muscle fibers of soleus attached to it. Beneath this the popliteal artery terminated into anterior tibial artery and tibio peroneal trunk, which can lead to popliteal artery entrapment.

In two specimens, popliteal artery was coursing more medially rather than lateral inclination, hence, can get entrapped by medial head of gastrocnemius.

In one specimen, popliteal artery was superficial to popliteal vein at the middle of popliteal fossa wherein popliteal artery can get entrapped by medial head of gastrocnemius the larger medial head of gastrocnemius arises from posterosuperior aspect of medial condyle of femur and adjoining popliteal surface of femur and descends down to meet the smaller lateral head.

In another specimen, popliteal artery was crossed by muscle belly of plantaris, which could lead to popliteal artery entrapment.

Fig.1: Trifurcation pattern [Type 1B], tibio peroneal trunk measuring 0.5cm in length.



PA – Popliteal artery, TPT – Tibio peroneal trunk, ATA – Anterior tibial artery, PTA - Posterior tibial artery.

Fig.2A: Hypoplastic PTA [Type 3A], peroneal artery coursing within the substance of flexor hallucis longus muscle.

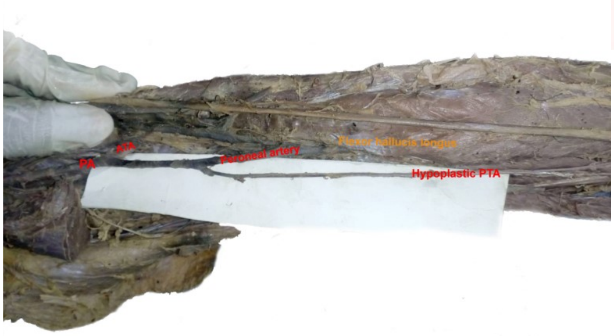


Fig.2B: Distally PTA replaced by peroneal artery.

Fig.3A: Aplastic PTA [Type3A]

Fig.3B: Distally PTA replaced by peroneal artery. Peroneal artery coursing beneath flexor retinaculum.

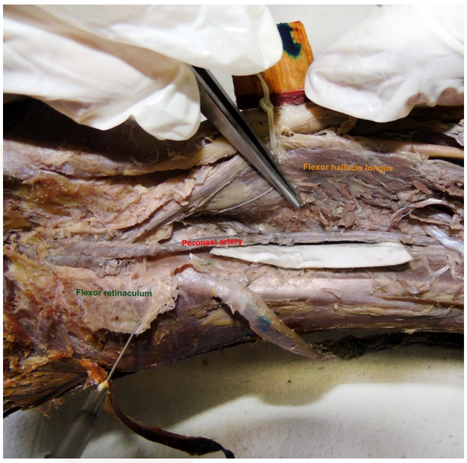


Fig.4: Larger peroneal artery with smaller posterior tibial artery.

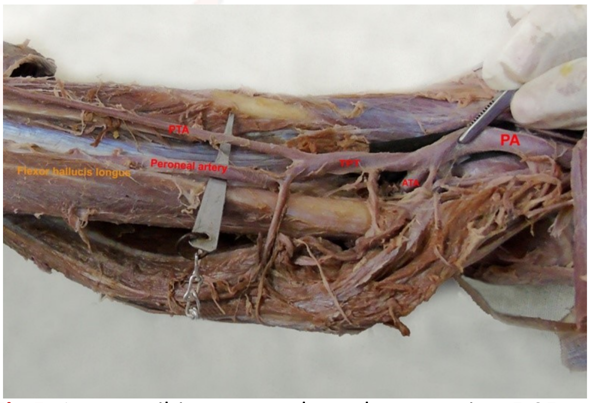


Fig.5: Longer tibio peroneal trunk measuring 5.25 cm from distal border of popliteus muscle.

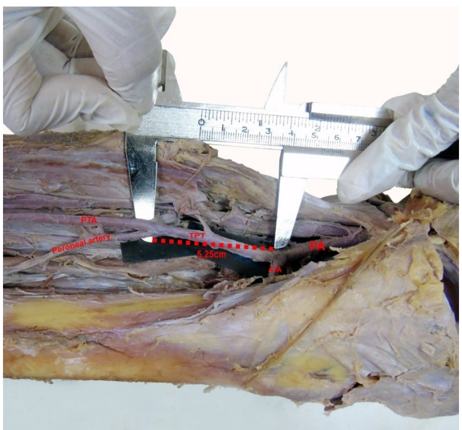


Table 1: Frequency of anatomical variations of branching pattern of popliteal artery.

Authors	Number of specimens dissected	1A (%)	1B (%)	1C (%)	2A-1 (%)	2A-2 (%)	2B (%)	2C (%)	3A (%)	3B (%)	3C (%)
Piral et al.[6]	40	90.9	5	5	0	0	0	0	0	0	0
Ozgur et al.[7]	40	90	2.5	2.5	5	0	0	0	0	0	0
Hemalatha J [8]	40	90	5	0	0	0	0	0	2.5	0	0
Present study	50	88	2	0	0	0	0	0	10	0	0

Fig.6: Popliteal artery coursing more medially towards medial head of gastrocnemius with shorter tibio peroneal trunk of 1.4 cm.

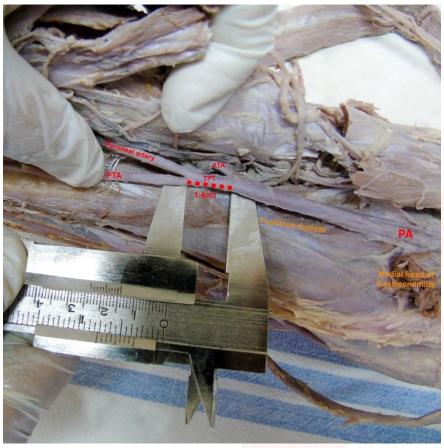


Fig.7A: Popliteal artery coursing beneath bony crest, from medial half of upper one third of posterior surface of fibula.

Fig. 7B: Popliteal artery bifurcating beneath bony crest into anterior tibial artery and tibio peroneal trunk.

Fig. 8: Popliteal artery superficial to popliteal vein, at the middle of popliteal fossa in close contact with medial head of gastrocnemius.

Fig.9: Popliteal artery crossed by slightly longer muscle belly of plantaris.

DISCUSSION

The morphological deviations in structure of organs or apart of the body, which do not mean a functional "handicap" for the individual, may be considered as an "anatomical variation" [9]. Variations of the arterial patterns or so-called "abnormalities" have received considerable attention in the anatomical literature. An "abnormality" does not in any way imply an inferior or less effective blood supply of the region, but is simply a variation or departure from the "normal" [10]. Most of the anatomic variations in the popliteal artery branching pattern can be explained by alterations in embryonic development. Anterior and posterior tibial arteries develop from the femoral artery, which is the continuation of the external iliac artery and main artery of the fetal lower limb, while popliteal and peroneal arteries develop from middle and distal segments of the axial or sciatic artery (arteria nervi ischiadica), the embryonic vessel that supplies the lower limbs. In developing embryos, the sciatic artery arises from the dorsal root of the umbilical artery and runs down the leg to the distal border of popliteus muscle; then it gives rise to a perforating branch, which anastomoses with the femoral artery. While the embryo grows, the size of the femoral artery increases and that of the sciatic artery decreases. This perforating branch, called ramus communicans, then gives rise to the definitive anterior tibial artery. The posterior tibial artery is formed by the anastomoses between distal femoral artery and the popliteal artery.

Most of the variations can be explained by combinations between persistent primitive arterial segments, abnormal fusions, hypoplasia and segmentary absence of this artery [11, 12]. Kim et al. [3] studied 472 limbs angiographically and classified branching pattern of popliteal artery using tibial plateau as the reference point. Our results agree with previous reports , the most frequent pattern being the type 1A, and the two variations in branching pattern observed in our study being trifurcation (type 1B) in 2% of specimens , and the hypoplasia/absence of the posterior tibial artery (type 3A type) in 10% of specimens (8% was complete absence and 2% were hypoplastic). In 4% of specimens, posterior tibial artery appeared smaller than peroneal artery.

Mavili et al. [13] described a pattern that consisted of a high bifurcation of the popliteal artery with a trifurcation pattern, which they called 2D. We did not find this branching pattern in our study.

Hemalatha J [8] observed that out of 40 specimens dissected, 37 specimens of popliteal artery showed division into anterior tibial artery and tibio peroneal trunk, in 2 specimens (5%) there was trifurcation), and in one specimen (2.5%) posterior tibial artery was absent. Alsharawy S et al. [14] found tibio peroneal trunk length lesser (about 1.3 cm) than normal and greater (about 3.7 cm) than the normal (2.5 cm). In our study, one specimen had tibio peroneal trunk length of around 1.4 cm, and the other specimen had a length of 5.25 cm.

The posterior tibial artery is often the main arterial supply to the foot in patients with clubfoot. Variations involving this vessel is of particular concern when these patients are managed surgically [15].

Arteriographic studies revealed that the most common vascular abnormality associated with clubfoot has been absent anterior tibial artery, reported in up to 85% of children with clubfoot. Hence, at the time of preoperative planning and surgical correction of clubfoot, it is best to assume the complete absence of the anterior tibial artery; consequently, great emphasis has been placed on protecting the posterior tibial artery and its terminal branch, the lateral plantar artery during clubfoot release operations to prevent ischemia of the foot [4].

In our study, we found the popliteal artery was coursing beneath bony process emerging from upper one third of posterior surface of fibula with muscle fibers of soleus attached to it. The bony extension could be the ossified fascia covering the muscle. Beneath this tunnel popliteal artery branched into anterior tibial artery and tibio peroneal trunk. This can lead to popliteal artery entrapment syndrome. Dar et al.[16] observed the tethering of popliteal artery to adductor magnus hiatus and to fascia related to soleus which was clinically important as it is vulnerable to traction during knee injuries e.g. dislocation. Di Marzo et al. [17] observed that the course of popliteal artery was around medial head of gastrocnemius muscle, which was compressing it and had aneurysmal changes distal to the external muscular compression. We encountered in two specimens, the popliteal artery was coursing more medial, deep to medial head of gastrocnemius and in another specimen popliteal artery was superficial to popliteal vein. In both conditions, popliteal artery can get entrapped beneath medial head of gastrocnemius. Several classifications of a number of variants of popliteal artery entrapment syndrome have been described. In the commonest of these, the popliteal artery enters popliteal fossa by curving medial to medial head of gastrocnemius. Several classifications of a number of variants of popliteal artery entrapment syndrome have been described. In the commonest of these, the popliteal artery enters popliteal fossa by curving medial to medial headof gastrocnemius. The artery then courses laterally, deep to medial head, between the latter and underlying medial condyle of femur. Popliteal artery entrapment syndrome is an unusual but important cause of peripheral vascular insufficiency, included in the differential diagnosis of acute popliteal artery occlusion, claudication or bizarre leg pains in young patients, especially men. Early diagnosis and surgical interventions are important for good operative outcome. Computerized tomographic angiography (CTA) appears to be the most useful single investigation in the diagnosis of PAES (Popliteal artery entrapment syndrome), but each imaging modality has its place and it may be appropriate to use in combination to make a firm diagnosis [18].

Popliteal artery entrapment syndrome should be treated by surgery regardless of the degree of symptoms. Surgical treatment technique is, releasing of the vessel by extracting the muscle that causes entrapment and reconstructing the narrowed lumen by endarterectomy or by-pass grafting. Treatment of the occlusion by angioplasty may be a proper approach after removal of the factor that causes entrapment [19, 20].

In our study, we observed that in one specimen, the popliteal artery was crossed by muscle belly of plantaris, which was slightly longer than usual. Gibson et al. [21] explained that the plantaris tendon might be the reason for popliteal artery entrapment syndrome. In their study, they reported an incidence of 3.8% out of 86 postmortem limbs.

It is of paramount importance for Orthopaedicians, Radiologists and Vascular surgeons to have a sound knowledge on these variations. Normal anatomical course and the variations of neurovascular structures have gained importance due to surgical interventions in the lower limb region. Distal popliteal arterial variations may influence the success of femoro distal, popliteal and tibial arterial reconstructions. Orthopaedicians should have a clear knowledge on the origin, course and branching pattern of posterior tibial artery before managing children with clubfoot, as it is the main arterial supply. Knowledge of these variations will be beneficial to angiographers for the evaluation of arteriogram, and to vascular surgeons for various surgical approaches in the lower extremity.

Procedures like angiography, duplex ultra sound, magnetic resonance angiography and computerized tomography, require the knowledge of normal pattern and its variations to avoid misinterpretation of the observations.

CONCLUSION

In the current millennium, the anatomical knowledge makes a successful diagnosis and provides proper treatment to the patient. The occurrence of variations in branching pattern of popliteal artery and its relation with surrounding structures is very important clinically. Awareness of these variations is a prime prerequisite for planning surgical and radiological interventions. We hope our study adds up to the existing knowledge on variations of popliteal artery and its branching pattern, and caters to extra information, in a way to help all clinicians to diagnose and treat the patients accordingly.

Conflicts of Interests: None

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