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Original Research Article

A Cadaveric Study of Prevalence of Variations in Surgical Anatomy of Popliteal Artery and Its Branching Patterns in Western Rajasthan Region

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Abstract

Introduction: The popliteal artery, a continuation of the femoral artery, is the primary blood supply to the leg and foot. Anatomical variations in its branching pattern, including trifurcation, high division, and differences in genicular and peroneal branches, are clinically significant for surgical interventions, vascular procedures, and diagnostic imaging. Population-specific data are essential to guide surgeons and radiologists in reducing intraoperative complications.

Objectives: To study the prevalence of anatomical variations in the popliteal artery and its branching patterns in cadaveric lower limbs from the Western Rajasthan population.

Methods: A cross-sectional observational study was conducted on on 25 lower limbs (14 male, 11 female) at the Department of Anatomy, Government Medical College, Pali, Rajasthan, after ethical approval from institutional ethical committee. Standard dissection protocols were used to expose the popliteal artery, documenting its origin, termination, branching patterns, and variations in genicular and peroneal arteries. Data were recorded and analyzed for prevalence and pattern of variations.

Results: Among the 25 lower limbs studied, variations in the popliteal artery were observed in approximately 32% of cases. Trifurcation patterns were noted in 12% of limbs, while high division of the artery was seen in 4%. Variations in genicular branches were observed in 16% of limbs. Male and female limbs showed comparable variation patterns, with no significant side predominance. These variations highlight the need for careful preoperative planning in vascular, orthopedic, and reconstructive procedures.

Conclusion: The popliteal artery in the Western Rajasthan population exhibits notable anatomical variations in its branching and termination patterns. Knowledge of these variations is crucial for surgeons, radiologists, and anatomists to enhance diagnostic accuracy, reduce surgical complications, and improve clinical outcomes.

Keywords: Popliteal artery, anatomical variation, branching pattern, trifurcation, high division, genicular arteries, cadaveric study, Western Rajasthan.

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Introduction

The popliteal artery, a continuation of the femoral artery is the principal blood supply to the leg and foot. It courses through the popliteal fossa, lying deep among the neurovascular structures, and typically bifurcates into the anterior tibial artery and the posterior tibio-peroneal trunk.

Along its course, the artery gives off muscular, cutaneous, and genicular branches that form critical anastomoses around the knee joint.[1-3]The anatomical positioning of the popliteal artery makes it particularly vulnerable to trauma, surgical injury, and iatrogenic complications during procedures such as knee arthroscopy, total knee arthroplasty, femorodistal bypass grafting, and lower limb revascularization.[4-6] Anatomical variations in the branching pattern of the popliteal artery including trifurcation, high division, and differences in genicular and peroneal arteries are clinically significant and can influence surgical planning, radiological interpretation, and patient outcomes.[2,7] Knowledge of these variations is essential to avoid intraoperative complications such as hemorrhage, thrombosis, or limb ischemia. Population-specific data are particularly important, as the prevalence and patterns of variation can differ geographically.[7-9]

The present cadaveric study was conducted at the Department of Anatomy, Government Medical

College, Pali, Rajasthan, with the aim of assessing the prevalence and types of anatomical variations in the popliteal artery and its branches in the Western Rajasthan population. The study provides critical baseline data for surgeons, radiologists, and anatomists to enhance diagnostic accuracy, surgical safety, and educational knowledge.

Aim and Objectives

Aim: To conduct a detailed cadaveric study of the popliteal artery and its branching patterns in specimens from the Western Rajasthan region, with emphasis on identifying clinically significant anatomical variations relevant to surgical practice

Objectives:

1. To determine the prevalence and pattern of anatomical variations in the origin, course, and termination of the popliteal artery in cadavers from Western Rajasthan.
2. To assess the prevalence and types of variations in the branching pattern of the popliteal artery in the studied population.

Materials and Methods

Study design: cross-sectional observational study.

Study Setting: Department of Anatomy, Government Medical College, Pali, Rajasthan

Study duration: Approx One year, after approval from the Institutional Ethics Committee

Study Population: The study population consisted of embalmed adult human cadavers preserved in the Department of Anatomy. Both right and left lower limbs were included for dissection and analysis.

Inclusion Criteria:

1. Adult human cadavers of either sex with fully preserved lower limbs.
2. Cadavers with intact musculoskeletal and neurovascular structures of the lower limb, allowing detailed dissection of the popliteal artery and its branches.
3. Specimens suitable for accurate documentation of anatomical variations without interference from pathological or traumatic changes.

Exclusion Criteria:

1. Cadavers with visible trauma, surgical scars, or prior interventions involving the lower limbs.
2. Cadavers with congenital anomalies, deformities, or malformations affecting the lower limb.
3. Specimens exhibiting gross pathological changes in the popliteal region, such as tumors, infections, or vascular disorders, which could alter normal anatomy.

Sampling method: Non-probability convenience sampling was used. All cadavers available during the study period and meeting inclusion criteria were included. Both lower limbs were dissected separately and labelled to ensure accuracy.

Study tool: A predesigned and pretested semi-structured proforma was used to record the identification number of each cadaver, the side of the limb (right or left), and observations of the popliteal artery including origin, course, termination, bifurcation patterns, and variations in genicular and peroneal branches. All observations were systematically documented for statistical analysis.

Procedure of Sampling and Data Collection: Each lower limb was assigned a unique identification number and the side (right or left) was noted using standard anatomical landmarks. Standard dissection protocols were followed: a horizontal incision was made at the posterior thigh, followed by a vertical incision extending to the heel. Skin and fascia were reflected, and muscles including hamstrings, gastrocnemius, plantaris, soleus, and popliteus were carefully retracted or detached to expose the popliteal artery.

The popliteal artery was traced from the adductor hiatus to the lower border of the popliteus muscle, documenting the bifurcation, terminal branches, and origin of the peroneal artery. Special care was taken to preserve the genicular branches and other vascular structures. Arteries were painted red, veins blue, and nerves yellow for clarity, and photographs were taken using a Canon 16-megapixel digital camera. All observations were recorded in the proforma. Variations were numbered, categorized, and analyzed for prevalence and type.

Ethics: Prior ethical permission was obtained from the Institutional Ethical Committee before starting the study.

Data analysis: The data from filled schedules was entered into Microsoft Excel which further was analysed using IPM SPSS 29.0.0 (Trial Version).Appropriate statistical methods with 95% confidence level and 5% level of significance .A p-value < 0.05 was considered statistically significant.

Table 1: Comparison of Side-Wise and Gender-Wise Distribution of Variations in Level of Termination of Popliteal Artery (n = 50 limbs)

Termination Level	Male Right (14)		Male Left (14)		Female Right (11)		Female Left (11)		Total (50)	
	No.	%	No.	%	No.	%	No.	%	No.	%
Below Popliteus (Normal)	13	92.9	13	92.9	10	90.9	10	90.9	46	92
Above Popliteus (High Division)	1	7.1	1	7.1	1	9.1	1	9.1	4	8
Total	14	100	14	100	11	100	11	100	50	100

Table 2: Comparison of Side-Wise and Gender-Wise Distribution of Variation in Mode of Termination (n = 50 limbs)

Mode of Termination	Male Right		Male Left		Female Right		Female Left		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Normal Bifurcation	10	71.4	10	71.4	8	72.7	8	72.7	36	72
Trifurcation	2	14.3	2	14.3	1	9.1	1	9.1	6	12
Other Variations	2	14.3	2	14.3	2	18.2	2	18.2	8	16
Total	14	100	14	100	11	100	11	100	50	100

Table 3: Comparison of Side-Wise and Gender-Wise Distribution of Variations of Superior Genicular Artery (n = 50 limbs)

Superior Genicular Pattern	Male Right		Male Left		Female Right		Female Left		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Normal	12	85.7	12	85.7	9	81.8	9	81.8	42	84
Single Trunk	1	7.1	1	7.1	1	9.1	1	9.1	4	8
Dividing Trunk	1	7.1	1	7.1	1	9.1	1	9.1	4	8
Total	14	100	14	100	11	100	11	100	50	100

Table 4: Comparison of Side-Wise and Gender-Wise Distribution of Variations in Level of Origin of Peroneal Artery (n = 50 limbs)

Level of Origin	Male Right		Male Left		Female Right		Female Left		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Normal	9	64.3	9	64.3	8	72.7	8	72.7	34	68
Low Level	2	14.3	2	14.3	1	9.1	1	9.1	6	12
Separate Trunk	3	21.4	3	21.4	2	18.2	2	18.2	10	20
Total	14	100	14	100	11	100	11	100	50	100

Table 5: Comparison of Side-Wise and Gender-Wise Distribution of Variations in Source of Origin of Peroneal Artery (n = 50 limbs)

Source of Origin	Male Right		Male Left		Female Right		Female Left		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Posterior Tibial Artery	10	71.4	10	71.4	8	72.7	8	72.7	36	72
Anterior Tibial Artery	1	7.1	1	7.1	1	9.1	1	9.1	4	8
Separate Trunk	3	21.4	3	21.4	2	18.2	2	18.2	10	20
Total	14	100	14	100	11	100	11	100	50	100

Results

The present study was conducted on 25 embalmed adult human cadavers (14 male and 11 female) at the Department of Anatomy, Government Medical College, Pali, Rajasthan, after obtaining approval from the Institutional Ethics Committee. Both right and left lower limbs were included, contributing a total of 50 lower limbs for detailed dissection and analysis. All specimens were selected according to predefined inclusion and exclusion criteria, and standard anatomical dissection protocols were followed. The study primarily focused on evaluating the origin, level and mode of termination, and branching patterns of the popliteal artery, along with variations in the genicular and peroneal arteries. In this study, 56% of the cadavers were male and 44% were female. Right and left lower limbs were equally represented (25 limbs each). Gender-wise distribution included 28 male limbs (14 right, 14 left) and 22 female limbs (11 right, 11 left). The popliteal artery originated normally from the adductor hiatus in all examined specimens. No variation in the origin of the popliteal artery was observed in the present study.

The termination of the popliteal artery at the lower border of the popliteus muscle, considered the

normal anatomical level, was observed in 46 limbs (92%). High division of the artery above the popliteus muscle was noted in 4 limbs (8%). Among male limbs, high division was observed in 2 right (7.1%) and 2 left (7.1%) limbs. Among female limbs, high division was seen in 1 right (9.1%) and 1 left (9.1%) limb. The distribution of high division was relatively comparable between sides and genders. Regarding the mode of termination, normal bifurcation into anterior tibial and posterior tibial arteries was the most common pattern, observed in 36 limbs (72%). Trifurcation into anterior tibial, posterior tibial, and peroneal arteries was noted in 6 limbs (12%). Other variations in branching pattern were observed in 8 limbs (16%). In male limbs, normal bifurcation was seen in 10 right (71.4%) and 10 left (71.4%) limbs, while trifurcation was identified in 2 right (14.3%) and 2 left (14.3%) limbs. In female limbs, normal bifurcation was observed in 8 right (72.7%) and 8 left (72.7%) limbs, whereas trifurcation was noted in 1 right (9.1%) and 1 left (9.1%) limb. The overall distribution of termination patterns did not show marked side or gender predominance.

Variations in the superior genicular artery were also documented. A normal branching pattern was observed in 42 limbs (84%), while variations were seen in 8 limbs (16%). These included single trunk patterns in 4 limbs (8%) and dividing trunk patterns in 4 limbs (8%). Among male limbs, the normal pattern was observed in 12 right (85.7%) and 12 left (85.7%) limbs. Among female limbs, normal branching was seen in 9 right (81.8%) and 9 left (81.8%) limbs. Variations were evenly distributed across both sides.

The level of origin of the peroneal artery was normal in 34 limbs (68%). A low level of origin was observed in 6 limbs (12%), while origin as a separate trunk was noted in 10 limbs (20%). In male limbs, normal origin was observed in 9 right (64.3%) and 9 left (64.3%) limbs. In female limbs, normal origin was seen in 8 right (72.7%) and 8 left (72.7%) limbs. Low origin and separate trunk variations were proportionately distributed between genders and sides.

With regard to the source of origin of the peroneal artery, origin from the posterior tibial artery was the most common pattern, observed in 36 limbs (72%). Origin from the anterior tibial artery was seen in 4 limbs (8%), and origin as a separate trunk was noted in 10 limbs (20%). The distribution of these patterns was similar between right and left sides and between male and female limbs.

Overall, anatomical variations in the branching and termination patterns of the popliteal artery were observed in approximately one-third of the examined limbs. Although minor differences were noted between genders and sides, no consistent predominance was identified. The findings demonstrate that significant anatomical variability exists in the popliteal artery and its branches in the Western Rajasthan population.

Discussion:

Variations in the branching pattern of the popliteal artery have been recognized since the classical anatomical descriptions of Richard Quain [10], followed by contributions from T. P. Anderson Stuart [11] and H. D. Senior [12], who emphasized the embryological basis of arterial variations. Buntaro Adachi later proposed a systematic classification of arterial branching patterns, discussed in historical reviews [13], which was further refined by Lippert and Pabst [14]. The most widely accepted modern radiological classification remains that of Kim et al. [15].

In the present study conducted on 50 lower limbs from 25 cadavers, the popliteal artery originated normally from the adductor hiatus in 100% of specimens. Standard anatomical texts such as Cunningham's Manual of Practical Anatomy [16] and Gray's Anatomy [17] describe the origin of the popliteal artery as a continuation of the femoral artery at the adductor hiatus, with variations more commonly affecting termination rather than origin. Earlier radiological and anatomical studies have similarly emphasized branching variability rather than origin anomalies [18,19].

With regard to the level of termination, the present study observed normal termination at the lower border of the popliteus muscle in 92% of limbs, while high division was noted in 8%. Classical studies by Trotter [20] and Keen [21] reported high bifurcation incidences ranging from 1% to 5%. Adachi's classification studies [13] also documented variable frequencies of high division. Modern angiographic analyses by Kil and Jung [22] and Kropman et al. [23] demonstrated comparable but variable incidences of high termination patterns.

Regarding the mode of termination, the typical bifurcation pattern was observed in 72% of limbs in the present study. Kim et al. [15] classified this as the normal Type I-A pattern and reported it as the most frequent configuration. Similar predominance of the usual bifurcation has been reported in CT angiographic and cadaveric studies by Calisir et al. [24], Celtikci et al. [25], and Tomaszewski et al. [26]. Trifurcation of the popliteal artery was observed in 12% of limbs in the present study. Classical literature summarized by Lippert and Pabst [14] documented lower incidences, typically between 0.4% and 5%. However, contemporary imaging-based studies have reported higher frequencies of trifurcation and variant tibiofibular trunk formations [22,24–26], supporting the

relatively higher incidence observed in the present series.

Rare termination patterns, including anomalous peroneotibial trunk formations and unusual tibial artery origins, have been described in isolated case reports and anatomical studies [27–29]. Although some rare variants reported in the literature were not encountered in the present study, minor branching variations accounted for approximately 16% of limbs, indicating considerable anatomical diversity.

Genicular artery variations have also been highlighted in surgical and anatomical studies. Sabalbal et al. [30] demonstrated that the classical genicular arterial anastomosis is not always present as depicted in textbooks. Kale et al. [31] and Lappas et al. [32] further emphasized variability in periarticular and infrapopliteal vessels. In the present study, superior genicular artery variations were observed in 16% of limbs, whereas absence of specific genicular branches was not noted, suggesting relatively fewer extreme genicular deviations compared to some published reports.

The peroneal artery also demonstrated variability. In the present study, it originated from the posterior tibial artery in 72% of limbs, as a separate trunk in 20%, and from the anterior tibial artery in 8%. Variations in peroneal origin have been extensively documented by Adachi [13], Kim et al. [15], Kil and Jung [22], and Tomaszewski et al. [26], though generally at somewhat lower frequencies than observed in the present study.

Overall branching variations of the popliteal artery were observed in approximately one-third of limbs in the present study. Classical studies by Quain [10], Adachi [13], and Keen [21] generally reported lower overall incidences, often below 10%. In contrast, modern cadaveric and radiological studies utilizing detailed classification systems and advanced imaging techniques have reported higher variation rates [15,22–26]. The relatively higher incidence observed in the present study may therefore reflect improved documentation methods as well as possible population-based anatomical differences.

Strength and Limitations:

The present study provides a detailed cadaveric evaluation of the branching pattern of the popliteal artery and its genicular and peroneal branches in a Western Rajasthan population, allowing direct visualization and precise documentation of arterial morphology. Equal inclusion of right and left lower limbs and representation of both male and female cadavers enhanced observational balance and reduced side bias.

The cadaveric dissection method permitted accurate identification of smaller branches, particularly the genicular arteries, which are often difficult to assess in radiological studies. However, the study was limited by a relatively small sample size of 25 cadavers (50 limbs), which may restrict the generalizability of the findings. Statistical analysis comparing gender- and side-based differences was not performed, limiting inferential interpretation. Additionally, as a cadaveric study, clinical correlation and age-related vascular changes could not be evaluated, and the findings represent a specific regional population that may not reflect wider demographic variability.

Conclusion:

The present study reveals a considerable incidence of variation in the branching pattern of the popliteal artery, including high division, trifurcation, and variations in the origin and level of the peroneal artery, along with notable changes in the genicular branches.

Although the origin of the popliteal artery was constant in all specimens, nearly one-third of the examined limbs demonstrated deviations in termination and branching patterns. When compared with previous reports, certain variations such as high division and separate trunk origin of the peroneal artery were observed with relatively higher frequency in the present study.

These findings emphasize the need for radiologists, vascular surgeons, and orthopedic specialists to have thorough knowledge of possible anatomical variations in the popliteal region. Awareness of these patterns is essential for accurate interpretation of angiographic imaging, safe performance of knee arthroplasty, arthroscopy, fracture fixation, and peripheral vascular procedures. A clear understanding of such variations can help minimize iatrogenic vascular injury, improve surgical planning, and ultimately enhance patient outcomes.

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