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A Study on Variations in the Branching Pattern of Axillary Artery in North Indian population

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Abstract: Introduction: Axillary artery, a continuation of subclavian artery, is the main (axis) artery to the upper limb. Normally it gives rise to six named branches before continuing as brachial artery. Variability in the origin of certain branches of the axillary artery is frequently apparent but not uniformly studied. The objective of this study is to present the abnormalities in the branching pattern of axillary artery with a view to clarification and quantification of both the "regularity" and "variability" in these vessels. **Aim**: The aim of this study is to present the variations in the branching pattern of axillary artery with a view to clarify and quantify both the "regularity" and "variability" in these vessels. **Material and Methods:** The current study was conducted on 40 formalin embalmed cadavers bilaterally, during routine dissection done at Punjab Institute of Medical Sciences, Jalandhar. The axillary artery and all of its branches were observed from their point of origin and traced to their termination, for any morphological variation. **Result**s: Out of a total of 80 limbs studied, 21 showed variant branching pattern of Axillary artery. Six types of variations were noted in its branching pattern, with one type of variation being present bilaterally in two cadavers. One of the variations is a rare and unique entity. The percentage of variations was also calculated to fulfil the objective of this study holistically. **Conclusion:** Such anomalous branching pattern may represent persisting branches of the capillary plexus of the developing limb buds. These variations have pragmatic importance for surgeons for accurate diagnosis and surgical procedures and also for vascular radiologists for construing angiographic images.

Keywords: Axillary, cadaveric, branching, morphological, variation, anomalous.

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INTRODUCTION

The axillary artery (AA) serves as the principal source of arterial supply to the upper limb, continuing from the subclavian artery and transitioning into the brachial artery. Traditionally, its course is described in three parts, each giving rise to a predictable set of branches namely Superior thoracic artery (STA) from the first part; Thoraco-acromial artery (TA) and Lateral thoracic artery (LTA) from the second part; and Anterior circumflex humeral artery (ACHA), Posterior circumflex humeral artery (PCHA) and Subscapular artery (SA) from the third part. However, numerous studies have demonstrated that the branching pattern of the AA exhibits considerable anatomical variability. Anatomical studies consistently demonstrate that variations in this branching pattern are frequent, with some researchers suggesting that a "variant" pattern may actually be more common than the classical description found in standard textbooks [1,2].

The reported incidence of variations in the AA's branching pattern varies significantly across different cadaveric studies. Astik and Dave [1] observed variations in 62.5% of the 80 limbs they dissected, noting that anomalies were more prevalent in the second and third parts of the artery. In a more recent study, Alashkham *et al.* [2] reported an even higher incidence, finding variations in 80% of specimens, with only 20% displaying the classical anatomical pattern bilaterally. Conversely, other studies such as that by Gadekar *et al.* [3] reported a lower variation rate of 26.66%, highlighting the demographic and possibly regional differences in vascular anatomy.

The third part of the AA, which extends from the lower border of the pectoralis minor to the lower border of the teres major, is the most frequent site for branching anomalies [2,3]. A frequently observed variation is the origin of multiple branches from a single common trunk rather than separate origins. The SA and the PCHA often arise from a common trunk, a phenomenon

observed in approximately 30% of cases [2]. The LTA, typically a branch of the second part, has been observed arising from the third part, often in conjunction with the PCHA [4].

Bifurcation and Trifurcation: Rare cases have documented the AA bifurcating into superficial and deep branches, where the deep branch gives rise to the SA, ACHA, PCHA and profunda brachii arteries [5].

Such variations hold significant clinical relevance, particularly in surgical procedures involving the axilla, shoulder, and upper limb; interventional radiology; regional anaesthesia; and trauma management. Unidentified arterial anomalies may increase the risk of intraoperative haemorrhage, complicate vascular repairs, or lead to inadvertent injury during diagnostic or therapeutic interventions. Understanding the spectrum and frequency of these variations is therefore essential for clinicians, anatomists, and radiologists. With the increasing use of advanced imaging techniques and minimally invasive procedures, precise anatomical knowledge has become even more crucial. This study aims to document and analyze the variations in the branching pattern of the axillary artery in a defined population, contributing to the existing body of literature and enhancing the anatomical understanding necessary for safe and effective clinical practice.

Although numerous variations in the branching pattern of the AA have been documented through individual specimen dissections, the prevalence of these findings in Indian population remains uncertain. In particular, variations involving the LTA, SA and PCHA have been noted but not consistently quantified. This study seeks to establish the frequency of these variant branching patterns, offering a more comprehensive understanding of their occurrence and potential clinical relevance.

MATERIALS AND METHODS

Study Design and Sample Size

The present descriptive anatomical study was conducted on 40 formalin-embalmed adult human cadavers available in the Department of Anatomy at Punjab Institute of Medical Sciences, Jalandhar over a period of four years from 2021 to 2025, after obtaining Ethical approval from Institutional Ethical Committee vide letter no. PIMS/ IEC/21/27 dated 25-02-2021. As each cadaver was examined bilaterally, a total of 80 AAs were included.

Inclusion criteria - Only cadavers with intact axillary regions and without evidence of prior surgical intervention, traumatic deformity, or pathological changes affecting the axilla were selected to ensure optimal visualization of vascular structures.

Embalming and Preservation

To ensure structural integrity and prevent post-mortem decomposition, the cadavers were embalmed immediately after death using a standard formalin-based preservative solution. The arterial system was infused via the femoral or common carotid artery to ensure thorough fixation of the vascular tissues.

Labeling and Identification

A systematic labeling protocol was adopted to ensure accuracy during data collection and analysis:

- **Cadaver Identification:** Each of the 40 cadavers was assigned a unique numerical identifier ranging from **1 to 40**.
- **Laterality:** The right and left limbs were clearly marked as R and L, respectively.
- This resulted in a total of 80 specimens (e.g., 1R, 1L, 2R, 2L) for comparative analysis between bilateral sides of the same individual.

Dissection Procedure

All dissections were performed following standard anatomical dissection protocols:

1. **Positioning of Cadavers:** Cadavers were placed in the supine position with the upper limbs abducted to approximately 90 degrees to allow full access to the axillary region.
2. **Exposure of the Axilla:** A skin incision was made along the anterior chest wall, extending laterally to the medial aspect of the upper arm. The skin, superficial fascia, and deep fascia were reflected systematically to expose the boundaries and contents of the axilla.
3. **Identification of the Axillary Artery:** The AA was identified as a continuation of the subclavian artery at the lateral border of the first rib and traced distally to its transition into the brachial artery at the inferior border of teres major. Surrounding structures, including the cords of the brachial plexus, axillary vein, lymph nodes, and fat, were carefully cleared to allow precise visualization of arterial branching.

Observation and Documentation of Branches

The AA and each of its branches were observed meticulously:

- The point of origin, course, and termination of the branches were noted.
- Particular attention was given to the branching patterns of the LTA, SA and PCHA.
- Any topographical variations, deviations from classical anatomical descriptions, or atypical branching relationships were recorded in detail.

High-resolution photographs were taken using a digital camera to document the observed variations.

Data Recording and Statistical Analysis

The data collected from the 80 limb dissections was tabulated and analyzed to determine the frequency and

distribution of vascular variations. Statistical comparisons between the percentages of different branching patterns—including comparisons between the right and left sides—were performed using the Chi-square test.

For all analytical procedures, a p-value of less than 0.05 ($p < 0.05$) was regarded as statistically significant, indicating that the observed variations were unlikely to have occurred by chance. All statistical calculations were processed using software IBM SPSS 21.

RESULTS

In this study, out of total of 80 upper limbs from 40 embalmed cadavers that were dissected and examined, the majority of the specimens adhered to the classical anatomical description of the axillary artery, but 21 limbs (26.25%) displayed significant variations in their branching patterns. These findings were categorized into six distinct types.

Type I: Rare High Bifurcation of the Axillary Artery

This was the most unique finding of the study, observed in 1 case (1.25%) on the right side of a male cadaver.

- The axillary artery gave off the Superior Thoracic (STA), Thoracoacromial (TA), and Lateral Thoracic (LTA) arteries normally.
- In its second part, just proximal to the formation of the median nerve, the artery bifurcated into two distinct branches:

Superficial Branch: This branch continued directly as the Brachial artery, situated medial to the median nerve. Notably, it did not give rise to the Profunda Brachii artery or the Superior Ulnar Collateral artery.

Deep Branch: This branch gave rise to all three standard branches of the third part of the AA (Subscapular and both Circumflex Humeral arteries). It then continued as the Profunda Brachii artery, which subsequently gave off the Superior Ulnar Collateral artery and a muscular branch before entering the spiral groove.

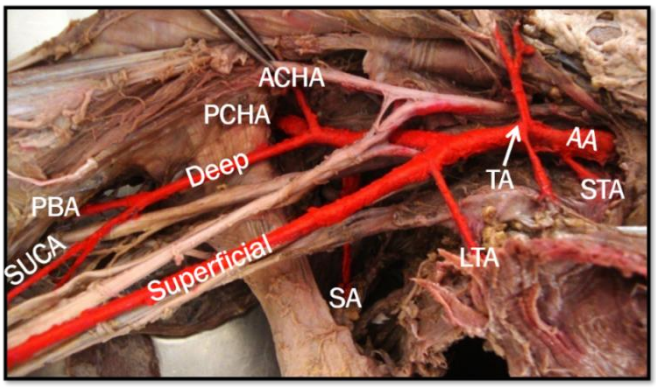

Fig-1: High bifurcation of Axillary artery (Type I)

Type II: Common Trunk for Subscapular and Lateral Thoracic Arteries

This single side variation was found in **7 cases (8.75%)**, with six occurrences on the right side and one on the left.

- A single common trunk arose from the second part of the AA.
- This trunk later divided into the SA and the LTA.
- After the division, both vessels followed their standard anatomical courses.

Fig-2: **Common Trunk for Subscapular and Lateral Thoracic Arteries (Type-II)**

Type III: Bilateral Common Trunk with Additional Thoracodorsal Artery

This variation was observed in 4 cases (5%), presenting bilaterally in two male cadavers.

- Similar to Type II, there was a common trunk for the SA and LTA.
- But, in 2 out of 4 cases, an Additional Thoracodorsal Artery (ATDA) was present.
- The ATDA ran parallel to the primary Thoracodorsal artery.
- The SA gave off the Circumflex Scapular artery and continued as the primary Thoracodorsal artery in the usual manner.

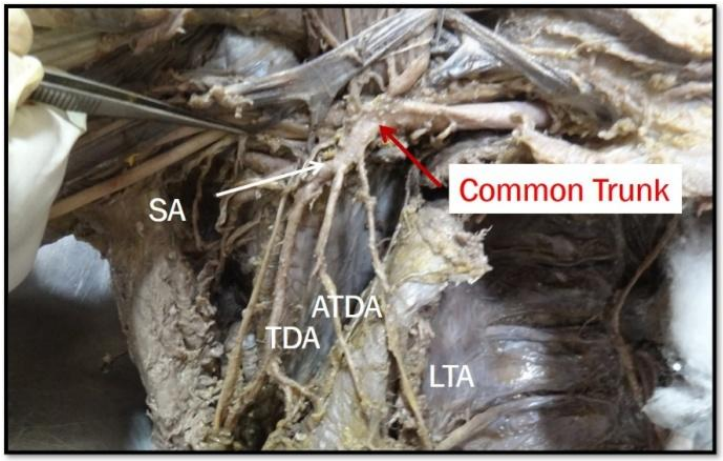

Fig-3: Bilateral Common Trunk with Additional Thoracodorsal Artery (Type III)

Type IV: Anomalous Origin of the Thoracoacromial Artery

This variation was identified in **4 cases (5%)**.

- The TA, which typically originates from the second part of the axillary artery, was found arising from the first part of the artery instead.

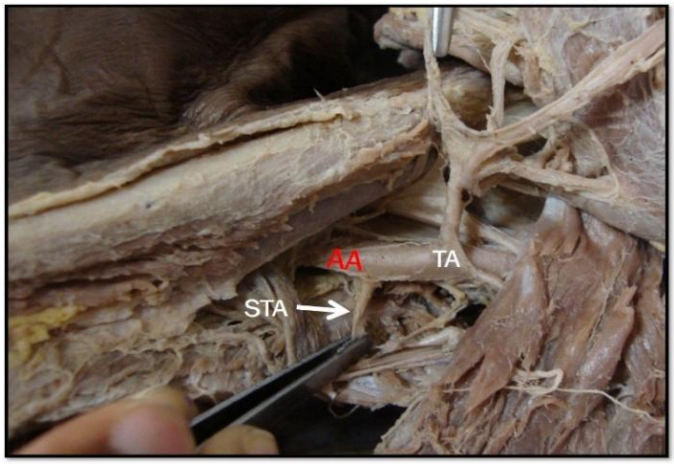

Fig-4: **Anomalous Origin of the Thoracoacromial Artery (Type IV)**

Type V: Absence of the Superior Thoracic Artery

This variation occurred in 3 cases (3.75%).

- The STA was completely absent.
- In these specimens, the blood supply to the first and second intercostal spaces was presumably derived from the TA or the internal thoracic artery.

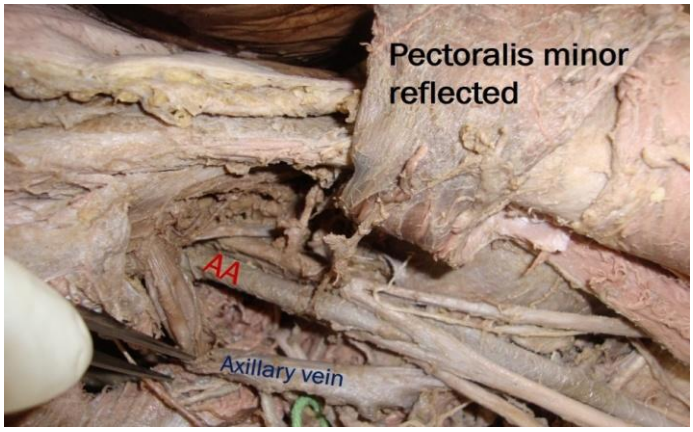

Fig-5: Absence of the Superior Thoracic Artery (Type V)

Type VI: Absence of Anterior circumflex humeral artery

This variation occurred in 2 cases (2.5%), both right sided and in female

- ACHA was found to be completely absent with a prolonged course of PCHA arising from SA and compensating for ACHA.

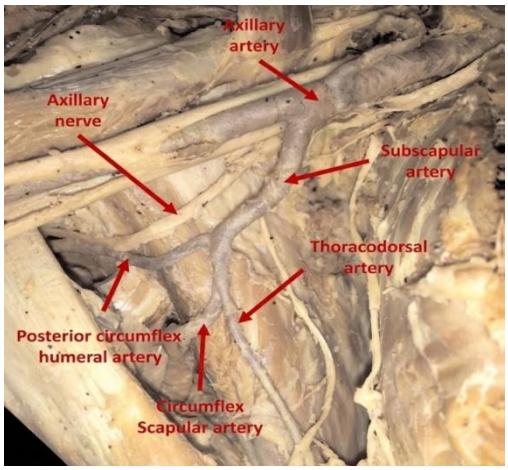

Fig-6: **Absence of Anterior circumflex humeral artery (Type VI)**

Side to side variations: Regarding the laterality of the observed anomalies, unilateral variations were predominant, accounting for 17 out of the 21 variant limbs. Within this group, a marked asymmetry was observed, as right-sided variations (12 cases) were significantly more frequent (more than double) as compared to the left-sided variations (5 cases), emphasizing the need for side-specific vigilance during clinical and surgical explorations of the axilla.

While variations were less frequent than the classical pattern, the presence of these anomalies, particularly the Type I bifurcation and the Type III bilateral complex trunks, proved to be statistically noteworthy ($p < 0.05$) in the context of clinical and surgical anatomy.

Table-1: Type-Wise Distribution of Variations

Variation Type	Description	No. of Cases	Frequency (%)
Type I	High Bifurcation of AA in the 2nd Part	1	1.25%
Type II	Common Trunk for SA LTA	7	8.75%
Type III	Bilateral Common Trunk (SA + LTA) with Additional Thoracodorsal (ATDA)	4	5%
Type IV	TA arising from the 1st Part	4	5%
Type V	Absence of STA	3	3.75%
Type VI	Absence of ACHA	2	2.5%
Total	**All Variations**	**21**	**26.25%**

Table-2: Comparison of variations with respect to gender and side involved.

	Gender		Side	
	Male	**Female**	**Right**	**Left**
Total limbs (n=80)	52	28	40	40
Variations (n=21)	12 (23.1%)	9 (32.1%)	14 (35%)	7 (17.5%)
Chi square test	p= 0.0891(Not significant)		**p=0.0328 (Significant)**	

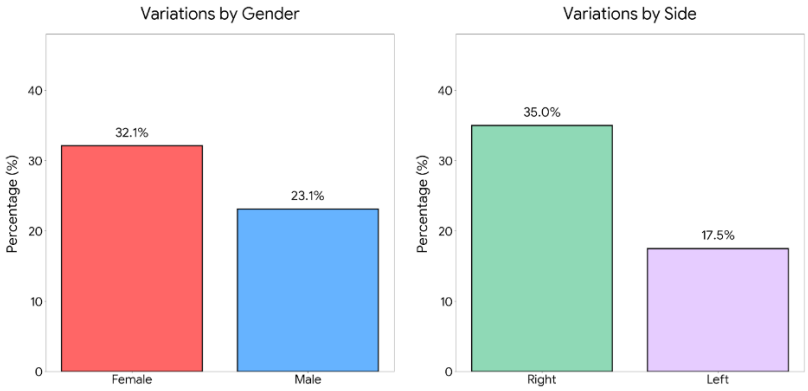

Fig-7: Comparison of variations with respect to gender and side involved

DISCUSSION

The anatomical branching pattern of the AA is characterized by significant variability, which poses inherent challenges and risks during surgical and interventional procedures in the axilla. In the present study, while the majority of specimens adhered to the classical six-branch description, a significant variation rate of 26.25% (21 out of 80 limbs) was observed. This prevalence aligns closely with both contemporary anatomical investigations and established literature, such as the findings of Gadekar *et al.* [3] and Umarani *et al.* [6], who reported variation rates within the 20% to 30% range. Similarly, the 26.25% incidence observed here provides a strong statistical correlation to recent studies by Bagoji *et al.* [7], who reported 20%, Gupta *et al.* [8] at 22.5%, and Goswami *et al.* [9] at 26.7%. While these figures are notably lower than high-frequency reports such as those by Astik and Dave [1] or the 80% incidence noted by Alashkham *et al.* [2] the latter specifically focusing on third-part deviations—such fluctuations likely reflect differences in regional demographics and the specific criteria used to define a variant. Furthermore, the common trunks identified in the current Type II and III specimens correlate with observations by Verma *et al.* [10], who identified subscapular-related trunks in approximately 32% of their cases. Collectively, these data reinforce the clinical reality that while the classical pattern remains the most frequent, variant branching is a recurring anatomical feature that must be anticipated by medical practitioners to ensure procedural safety.

Analysis of Variant Patterns

The High Bifurcation (Type I)

The most unique finding of this study was the rare high bifurcation of the AA in its second part, occurring in 1.25% of cases. This variation is particularly notable because the "Superficial Branch" continued as the brachial artery without giving rise to the Profunda Brachii artery, while the "Deep Branch" served as the source for all third-part branches and eventually the Profunda brachii artery. A similar bifurcation has earlier been reported rarely [11] where at the level of the second rib's lower border, the axillary artery exhibited a high division into superficial and deep stems, with the lateral and medial cords of the brachial plexus situated between them.

Clinical Significance: Such a bifurcation can lead to confusion during arterial cannulation or when performing a brachial plexus block. If a surgeon or radiologist is unaware of this deep-seated division, they may inadvertently injure the deep branch, compromising the blood supply to the posterior compartment of the arm and the scapular region.

Common Trunks and Accessory Vessels (Types II & III)

Variations involving common trunks (SA and LTA) and additional vessels were the most frequent in this study, totaling 13.75% (Types II and III).

Type II: The origin of the SA and LTA arteries from a common trunk in the second part is a well-documented variation. Furthermore, the 13.75% frequency of common trunks (Types II and III) corroborates well-documented patterns where the LTA frequently deviates from its textbook origin, often arising from a common trunk with the SA in approximately 10% of cases [12] or even the TA [13].

Type III: The presence of an **Additional Thoracodorsal Artery (ATDA)** running parallel to the primary vessel is a critical finding for plastic surgeons.

The thoracodorsal artery is the primary pedicle for the latissimus dorsi (LD) flap. The identification of ATDA mirrors extremely rare cases previously described in literature, which are of paramount importance for the success of latissimus dorsi flap harvesting to avoid unexpected hemorrhage or graft ischemia [14].

Shifts in Origin and Absence (Types IV, V, & VI)
The anomalous origin of the (TA) from the first part (5%) and the absence of the STA or ACHA highlights the plasticity of axillary vascularization. The shift of the TA to the first part—a "high branching" pattern has also been noted by Odeh *et al.* [15].

Landmark Recognition: The TA is a primary landmark for identifying the second part of the axillary artery. Its shift to the first part can lead to the misidentification of arterial segments during imaging or surgical exploration.

Vascular Compensation: In Type VI cases where the ACHA was absent (2.5%), the PCHA was found to follow a prolonged course to compensate. This indicates a robust compensatory mechanism; however, the reliance on a single circumflex vessel increases the risk of ischemia to the humeral head in cases of proximal humeral fractures or shoulder dislocations.

Embryological Basis
The development of the arterial system in the upper limb is a complex process involving the selection of specific channels within a primitive capillary plexus. The axial artery of the limb is derived from the 7th cervical intersegmental artery.

Sprouting and Regression: According to the "Sprouting Theory," variations occur when certain branches that usually regress instead persist, or when new sprouts emerge at atypical levels.

Bifurcation Mechanism: The Type I bifurcation likely arises from an early division of the axial artery where two channels persist—one superficial and one deep—rather than the usual regression of the deep channel in favour of a single main trunk.

Clinical and Surgical Implications
The findings of this study have direct implications for several medical specialties:
General and Oncological Surgery: During radical mastectomies and axillary lymph node dissections, the surgeon must identify and preserve the long thoracic and thoracodorsal nerves. The presence of variant trunks (Types II and III) complicates this, as nerves and vessels often maintain a close, albeit variant, spatial relationship.
Orthopedic Surgery: The circumflex humeral vessels are at high risk during the reduction of shoulder dislocations. Knowledge of the absent ACHA (Type VI) and compensatory PCHA is vital to prevent iatrogenic avascular necrosis.

Radiology: Interventional radiologists utilizing the axillary artery for catheterization or treating aneurysms must be aware of the 26.25% variation rate to ensure accurate catheter placement and avoid complications.

Cardiovascular Surgery: The axillary artery is frequently used as a site for cannulation in cardiopulmonary bypass. The identification of a high bifurcation (Type I) is essential to ensure adequate systemic perfusion.

CONCLUSION

To conclude, while the classical branching pattern remains the most frequent, significant variations are encountered in nearly one-fourth of the population. The rare bifurcation and complex common trunks identified in this study provide a critical anatomical map for practitioners, emphasizing that meticulous preoperative imaging and careful intraoperative dissection are essential for ensuring patient safety in the axillary region.

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