Research Paper

Axillary Artery and the Variations of Its Branching Pattern in KwaZulu-Natal Populations: A Cadaveric Study

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ABSTRACT

Introduction: The axillary artery (AA) is a significant blood vessel located in the axilla that supplies the lateral thorax, upper limb, and axilla through the six branches it gives off from its course. This artery exhibits variations in origin and branching patterns, but its laterality and sex-related variations remain poorly explored, especially in the KwaZulu-Natal (KZN) population. This study aimed to document possible anatomical variations in the origin and length of the AA in the KZN population by sex and laterality.

Methods: This study was conducted on 20 human cadavers of a white South African ethnic group (40 upper limbs), provided by the Discipline of Clinical Anatomy at the University of KZN–Nelson R Mandela Medical School campus. Detailed dissection instructions were followed using Grant's dissector manual to carefully expose and examine the AA's variations in the origin of its branches and length.

Results: The third part of the AA had the highest frequency of variations (45%) in both men and women. However, females had the most significant number of variations (54.54%) on the right side in the third part. Three types of variations occurred mainly in the third part. The first part had the fewest variations. The length of the AA varied with sex and laterality, but females had a longer average length of 129.10 mm in this study.

Conclusion: This study reveals that variations in the AA origin and branching patterns differ by laterality and are sexually dimorphic, a finding that could assist surgeons and radiologists in avoiding pitfalls and complications of procedures performed in the axilla.

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Introduction

The axillary artery (AA) is one of the contents of the axilla region, in addition to the axillary vein, brachial plexus, and axillary lymph nodes. It begins at the lower border of the first rib, as a continuation of the subclavian artery, and terminates at the outer border of the teres major muscle [1]. The AA supplies blood to the surrounding structures and muscles of the axilla, such as the pectoralis major, pectoralis minor, serratus anterior, breast, deltoid, subscapularis, humeral head, and glenohumeral joint [2].

The AA has several anatomical relations, and one of the structures related to this great vessel is the pectoralis minor muscle (PMM). The PMM lies superficial to the AA, thus separating the AA into three divisions: Superior (first), posterior (second), and inferior (third) to the PMM [3]. Each division of the AA gives off branches. The branches are mainly the superior thoracic artery (STA), lateral thoracic artery (LTA), thoracoacromial artery (TAA), anterior circumflex humeral artery (ACHA), posterior circumflex humeral artery (PCHA), and the subscapular artery (SSA) [4]. The STA is the first branch that arises from the first division, which is superior to the PMM [5]. The LTA and TAA arise from the second division, which lies beneath the PMM [6]. The last three branches, which are the PCHA, ACHA, and SSA, arise from the third division of the AA, which is inferior to the PMM [7, 8].

The six branches of the AA supply the different muscles and structures found in the region of the axilla. Muscles, such as pectoralis minor and major, are supplied by the STA branch [9]. The clavicle, deltoid muscle, acromion, and pectoralis muscles are supplied by the four terminal branches of the TAA. Pectoralis minor and major muscles, the serratus anterior muscles, and the female breast receive their blood supply from the LTA [10]. The PCHA supplies blood to the glenohumeral joint, deltoid, and triceps brachii. The ACHA supplies the head of the humerus and anastomoses with the PCHA around the surgical neck of the humerus. The largest branch of the AA, the subscapular trunk, divides into the thoracodorsal artery, which supplies the latissimus dorsi muscle, and the scapular circumflex artery, which supplies the scapular area [11].

The AA branching pattern shows a variation in the origin of its branches [12]. Various studies have examined the different variations in the AA branching pattern. In a study by Odeh et al. (2023) [13], the STA was absent in the first division of the AA, and branches of the lateral thoracic and TAA arteries arose from the first part instead of the second part. Furthermore, the third part of the artery, only the ACHA, arose from it. Saeed et al. (2002) [14] in their study discovered that a TAA trunk arose as a branch of the second division of the AA, and the trunk branched into the LTA, SSA, and PCHA. Sreeja et al. (2014) [15] reported a case in their study in which the CT, the third part of the AA, SSA, PCHA, and ACHA shared a common origin (CO) from the CT.

Furthermore, a previous study has attributed several variations observed in the branching patterns of AA to their developmental origin, deviating from the normal [16]. These distinctive morphological features of the AA pose a problem in clinical practice due to disparities between the features encountered in anatomy courses and those encountered in clinical practice [16, 17]. Therefore, knowledge of various branching patterns not only aids anatomists in understanding the variations in branching patterns but also aids surgeons, radiologists, and orthopaedicians during surgical procedures [18]. For instance, detailed knowledge of morphological variations in the origin and branching patterns of the axillary arteries is essential for identifying their pathological conditions and providing appropriate interventions, such as brachial plexus blocks and surgical repair of trauma to the axillary region [6, 19].

Several studies have been conducted on the morphology of the AA, its relationship with the PMM and variations in its branching patterns. However, there is a knowledge gap about variations in the origin and the lengths of the AA branches according to sex and laterality in the KwaZulu-Natal (KZN) population. Hence, this study was designed to observe, measure, and document the morphology and morphometry of the AA with respect to sex and laterality in the KZN population.

Materials and Methods

The equipment used for the dissection of the cadavers included dissecting instruments, such as a scalpel and a removable blade, tweezers, dissection forceps, needles, pins, and dissection fluids.

Sample size

This study was conducted on 20 human cadavers of different sexes (9 males and 11 females), ages (56-99 years), and populations (white) provided by the Clinical Anatomy Department at the University of KZN–Nelson R Mandela Medical School campus.

Dissecting procedure

Dissection of the axillary region to expose the AA was performed per the Grant's Dissector, 16th edition, by Alan J. Detton. The following dissecting instructions were followed: Skin incisions were made from the midline of the jugular notch to the xiphisternal joint. This was followed by an incision from the jugular notch laterally to the acromion of the clavicle and from the acromion to the lateral side of the arm. Finally, an incision was made from the xiphisternal to the costal margin. The skin was reflected to expose the pectoralis major and PMM. The upper limb was abducted to 45 to fully expose the axillary region. An axillary sheath was located within the axilla, and blunt dissection was performed to open the sheath, exposing the axillary vessels. The brachial plexus surrounded the AA. Images of the specimens were taken, and a qualitative description of the male and female AA variations was observed and documented.

Morphological analysis

The morphology of the AA was observed, with particular focus on the type of AA variation observed in each part of the AA.

Morphometric analysis

To observe the morphometry, a digital vernier caliper was used to measure the length of the AA. It was measured from the point where the AA begins, beyond the lateral border of the first rib, to the point where it terminates at the lower border of the teres major muscle. Measurements were taken at the midpoints of the AA width between the points where it began and terminated, as described by Majumdar et al. (2007) [11]. All measurements were recorded in millimetres to two decimal places.

Statistical analysis

The data were collected by a single observer, with all measurements repeated three times and an arithmetic average taken to minimize observer bias. A paired Student's t-test was used to compare the right and left AA. An unpaired t-test was used to compare males to females. Thereafter, McNemar's test was used to compare laterality and sex for the different parts of the AA. Statistical significance was set at A $P \leq 0.05$.

Results

Morphology of AA

Table 1 presents the types of variations observed in each part of the AA. The results on the incidence of variations across various parts of the AA showed that the first part had only one type of variation, observed on the left side in 9.1% of females. The second part had three variations on the left and one on the right, with 22.22% and 18.18% occurring in males and females, respectively. The third part showed three variations on the left and six on the right, with 33.33% male and 54.54% female.

Table 2 presents the types of variations observed in each part of the AA. The first part had the fewest variations, followed by the second part, and lastly the third part, which had the greatest number of variation types, amounting to three types. The first part had no STA as a variation, and such variation occurred on the left 5% (n=1/20) in 9.10% (n=1/11) females. In the second part, only 2 types of variations were observed. The LTA+TTA had a CO on the left, 5% (n= 1/20) in males, 11% (n = 1/9). CO of the LTA + SSA was also observed in males, 11.11% (n=1/9) on the left side, 5% (n=1/20). The third part was observed to have a CT of the ACHA+PCHA in females, 27.27% (n=3/11) on the right, 10% (n=2/20), and 5% (n=1/20) on the left. Furthermore, the SSA+ACHA+PCHA+deep brachial artery (DBA) had a CT on the right side, 15% (n=3.20) for both males, 22.22% (n=2/9), and females, 9.10% (n=1/11). Lastly the ACHA+PCHA+SSA had a CT on the right 5% (n=1/20) of females and 9.10% (n=1/11) of females only.

Morphometric analysis of the AA

The results of these findings on the association between respect for sex and laterality revealed that the length has a P=0.053 across both sexes and laterality combined. Although the left side is longer than the right, at 129.20 mm and 128.81 mm, respectively, it is borderline. The left side for both males and females has a P=0.27, which is regarded as not significant. Furthermore, the average length of females and males was 129.61 mm and 128.70 mm, respectively. The right side for both males and females has a P=0.44, which is not statistically significant. Moreover, the average length of the reads is 129.10 mm in females and 128.45 mm in males. Although not significant, it can be observed that, on both the left and the right sides, females have a longer AA length.

Table 1. Incidence of anatomical variations in the different parts of the AA

Part of AA with Variation	Left (n=20)	Right (n=20)	Total (n=40)	%		
				Male (n=9)	Female (n=11)	Total (n=20)
1st	1	0	1	0	9.1	5.0
2nd	3	1	4	22.22	18.18	20
3rd	3	6	9	33.33	54.54	45

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Table 2. Types of variations found in this study

Part of AA	Type of Variation	%				
		Left (n=20)	Right (n=20)	Male (n=9)	Female of (n=11)	Total
1st	No STA	5.00	-	-	9.10	14.1
2nd	LTA+TTA=CO	5.00	-	11.11	-	16.11
	LTA+SSA=CO	5.00	-	11.11	-	16.11
3rd	SSA+ACHA+PCHA+DBA=CT	-	15.00	22.22	9.10	46.32
	ACHA+PCHA=CT	5.00	10	-	27.27	42.27
	ACHA+PCHA+SSA=CT	-	5.00	-	9.10	14.1

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Abbreviations: AA: Axillary artery; STA: Superior thoracic artery; LTA: Lateral thoracic artery; ACHA: Anterior circumflex humeral artery; PCHA: Posterior circumflex humeral artery; SSA: Subscapular artery; CT: Common trunk; DBA: Deep brachial artery; CO: Common origin.

Discussion

Variations in the origin and branching patterns of AA are of great importance, especially for clinicians and surgeons to avoid pitfalls during interventional procedures involving the axilla. Although several studies have documented variations in origin and branching patterns, adequate attention has not been given to laterality and sex in the study population. Thus, this study was conducted to assess variations in the origins and branching patterns with respect to laterality and sex.

The present investigation found that variations in the AA occurred 5% in the 1st part, 20% in the 2nd part and 45% in the 3rd part (Table 3). The existing literature (Table 4) showed the least occurrence of variations in the

Table 3. The comparison of the length of the aa with respect to sex and laterality

Parameter	Laterality	Sample (n)	No.	Min	Max	Mean±SD	P
Length of AA (mm)	Left	Males	9	126.85	130.53	128.70±1.57	0.27
		Females	11	127.00	132.53	129.61±1.93	
	Total (left)		20	126.85	132.53	12.20±1.79	0.053
	Right	Male	9	126.85	130.96	128.45±1.76	0.44
		Female	11	126.00	130.54	129.10±1.91	
	Total (right)		20	125.62	131.54	128.81±1.83	0.053

*P≤0.05 indicates statistical significance.

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Table 4. Comparison of occurrences of the variations in the different parts of AA

Variation in AA	Udayasree et al. (2016) [20]	Chakraborty and Sarkar (2019) [21]	Present Study 2023
Sample Size	30	25	20
1st part (%)	1.7	0	5.0
2nd part (%)	11.7	6	20
3rd part (%)	21.6	16	45

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Table 5. Comparison of the types of variations

Authors	Sample No.	%					
		No. STA	LTA+TAA (CO)	LTA+SSA (CT)	SSA+ACHA + PCHA + DBA (CT)	ACHA+PCHA	ACHA + PCHA + SSA (CT)
Astik and Dave (2012) [16]	80	-	-	20.00	-	15.00	10.00
Fontes et al. (2015)[22]	24	-	-	-	-	8.30	-
Yang et al. (2021)[7]	59	-	-	-	-	32.00	3.38
Current study	20	14.1	16.11	16.11	46.32	42.27	14.1

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Abbreviations: STA: Superior thoracic artery; LTA: Lateral thoracic artery; TAA: Thoracoacromial; ACHA: Anterior circumflex humeral artery; PCHA: Posterior circumflex humeral artery; SSA: Subscapular artery; DBA: Deep brachial artery; CT: Common trunk.

1st part followed by the 2nd part and the 3rd part. Similarly, a study by Udayasree et al. (2016) [20] reported that variations occurred at 1.7% in the 1st part, 11.7% in the second part, and 21.6% in the third part. Chakraborty and Sarkar (2019) [21] reported 0% variation in the first part, 6% in the second part, and 16% in the third part. These previous studies and the present study have established that the most frequent variation in the AA occurs in the third part, regardless of race/ethnicity. However, in all these previous investigations, the variations in the AA with respect to sex and laterality remained poorly explored. Although previous studies considered larger sample sizes (30 and 25) than the present study, we observed a higher frequency of variations in females and on both the left and right sides of the third part, as shown in Table 1. This indicates that branching pattern variations of AA may be more frequent in the KZN population.

In terms of branching patterns, previous studies have reported variations observed in different parts of the AA (Table 5), with the most common being branches arising from a CT. In a study conducted by Astik and Dave (2012) [16], the authors observed 20%, 15%, and 10% occurrences of the LTA+SSA, ACHA+PCHA, and ACHA+PCHA+SSA arising from a CT. Fontes et al. [22] in their study found the ACHA+PCHA to arise from a CT in 8.30% of their sample of 24 cadavers. Yang et al. (2021) [7] observed ACHA+PCHA arising in 32% of their sample and ACHA+PCHA+SSA originating in a CT in 3.38%. Some of these variations were not compared by sex or laterality, but it is important to note that most occurred in the third part of the AA, which supports the data in Table 4. The present study observed multiple variations of the AA wherein the first part, no STA occurred in 14.1% of cases (Figure 1). The

Table 6. Comparison of the average lengths

Authors	Average Length of AA (mm)
Sirisha et al. (2019) [23]	101.7
Yang et al. (2021) [8]	112.2
Current study	128.81

AA: Axillary artery.

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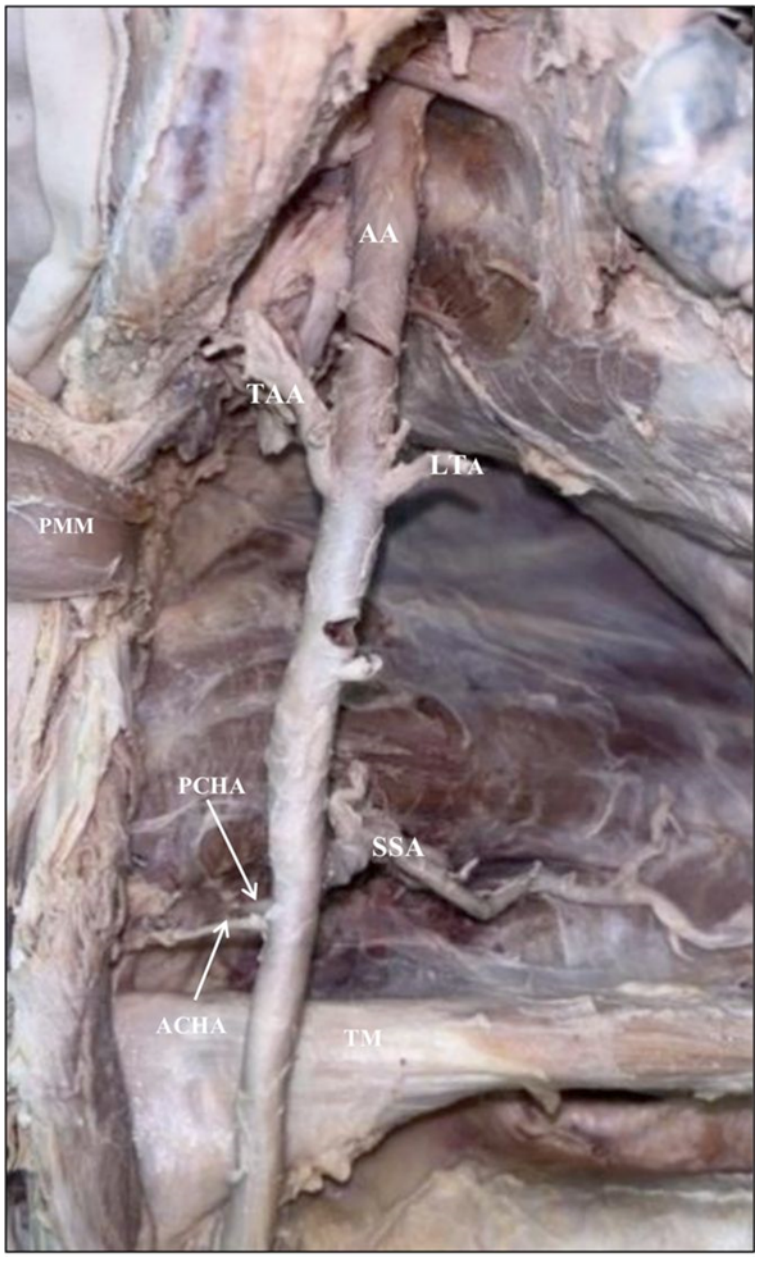

Figure 1. Illustrations of the types of variations

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Abbreviations: LTA: Lateral thoracic artery; TAA: Thoraco-acromial artery; ACHA: Anterior circumflex humeral artery; PCHA: Posterior circumflex humeral artery; SSA: Subscapular artery.

Note: Figure 1 shows the types of variations observed in this study, with the apparent absence of the STA.

variation of the LTA+TAA was of a CT between the two branches and occurred in 16.11% cadavers (Figure 2). The current study observed a CT where both the LTA and SSA arose in 16.11% (Figure 3), which supports the findings of the same variation by Astik and Dave (2012) [16]. Another variation documented in the current study was the SSA+PCHA+ACHA+DBA arising from the CT (46.32%; Figure 4). Furthermore, the current study noticed another CT for the ACHA+PCHA in 42.27%, this variation was relatively common in all the previous studies (Table 5). It is important to reiterate that more branching patterns were observed in this study compared to all previous investigations, suggesting a unique anatomical variation in the AA's branching patterns that requires special attention when performing surgical procedures in the axillary region.

In terms of AA morphometry with respect to sex and laterality, the present study found that Aa length is longer in the study population than in previous studies (Table 6).

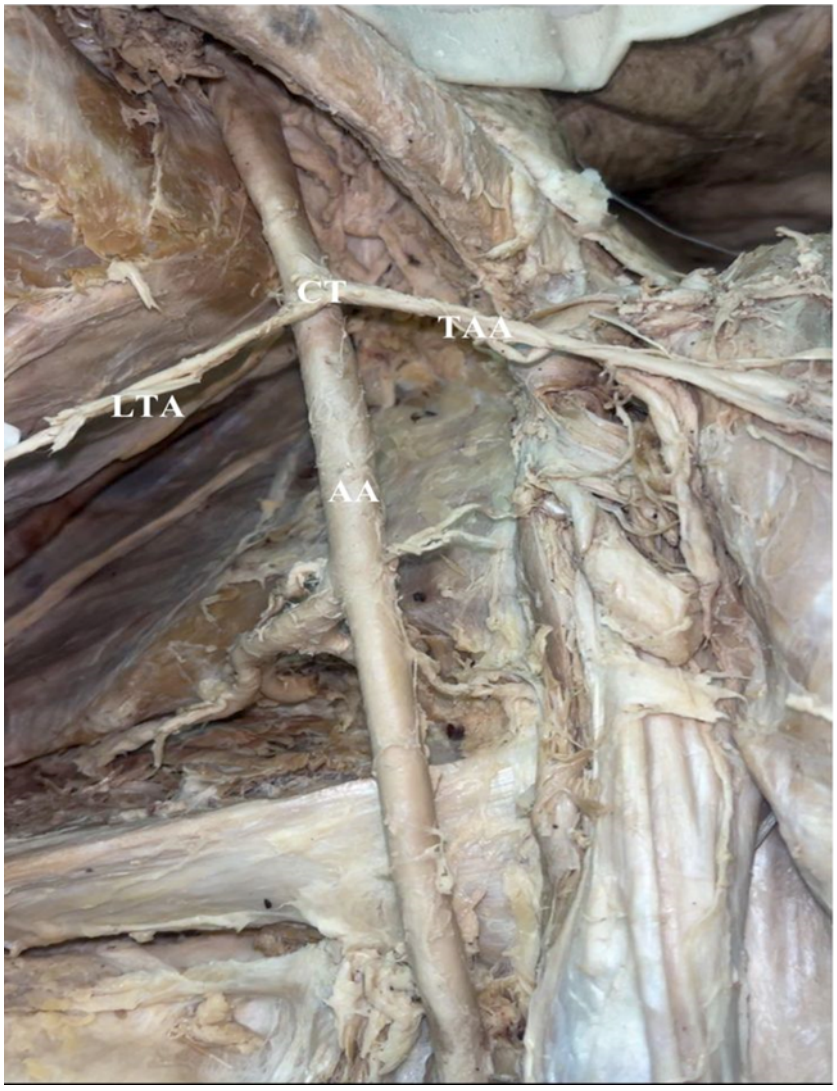

Figure 2. Morphological variation with CT
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Abbreviations: LTA: Lateral thoracic artery; CT: Common trunk; TAA: Thoracoacromial artery; AA: Axillary artery.
Note: Figure 2 shows the variations where LTA and the TAA have a CO.

In their investigation, Sirisha et al. (2019) [23] found the average AA to be 101.7 mm, whereas Yang et al. (2021) [7] observed an average length of 112.2 mm. However, the present study observed an average length of 128.81 mm (Table 6). Although not significant, it was observed that females had a longer AA in both the left and right than males. This study provides more information about the anatomy of AA by exploring its morphological and morphometric features by sex and laterality, which have been less explored. All these previous studies, in addition to the findings of this study, suggest that attention should be given to females when performing surgical procedures, especially on the third part, since it has frequent variations.

Conclusion

The results of this study revealed that the most frequent variation in the AA was in the third part, with 5% in the first part, 20% in the second, and 45% in the third. The study also noted more frequent variations in females and on both the left and right sides in the third part. The findings of this investigation show that variations in AA origin and branching patterns differ by laterality and are sexually dimorphic in the KZN population. This study has the potential to assist anatomy educators in understanding variations in the origins and branching patterns of the AA. It may also aid orthopaedicians, general surgeons, and radiologists in avoiding pitfalls and complications of procedures performed in the axilla, with minimal risk of damage to the AA's origin, course, and branches.

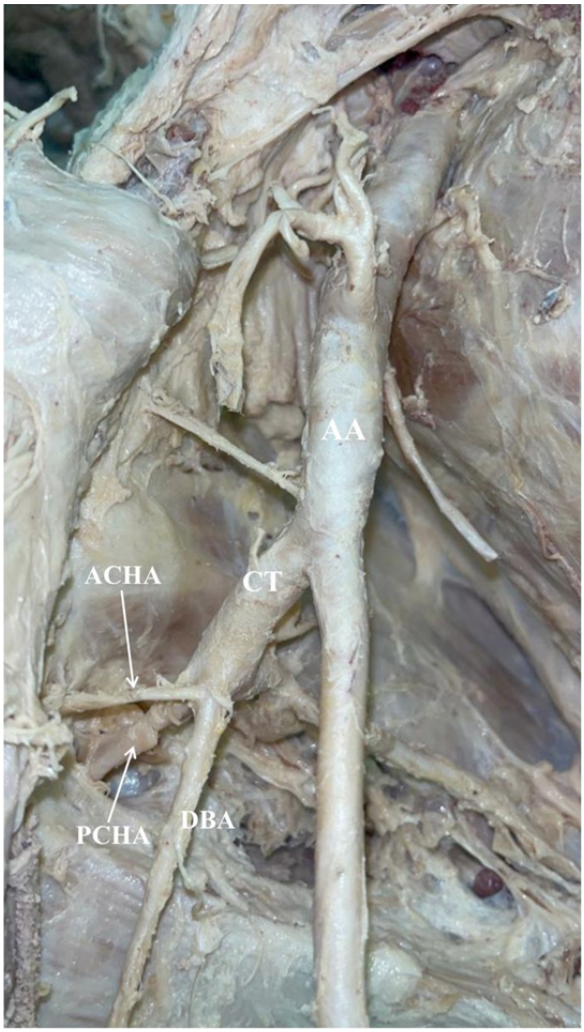

Figure 3. Variation in the branching patterns
Note: Figure 3 shows the variation in the branching pattern of AA, where the ACHA, PCHA, and the DBA arise from a CT.

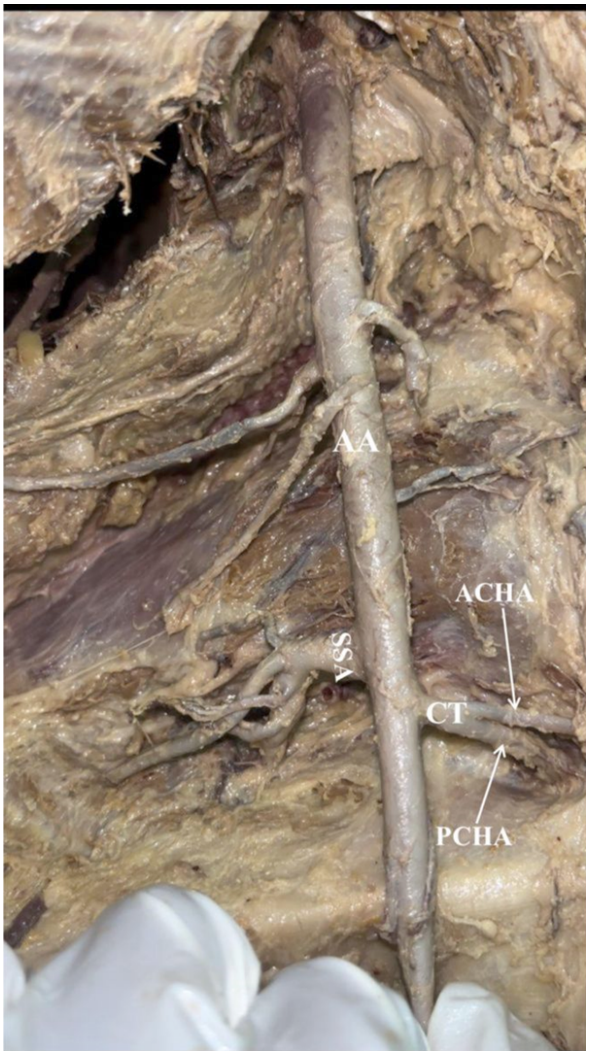

Figure 4. Morphological variation of AA
Note: Figure 4 shows the ACHA and the PCHA arising from a CT.

Limitations

The major limitation of this study was the sample size. Also, the current study was conducted using only white cadavers, which may not be a true representation of other population groups.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of University of KZN, Durban, South Africa (Code: 00005966/2023).

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Authors' contributions

Investigation, Writing the original draft, review & editing: Samuel Oluwaseun Olojede, Khayakazi Mayenziwe Mthembu, Nomthandazo Magcaba, Sodiq Kolawole Lawal, Onyemaechi Okpara Azu, and Edwin Coleridge Naidu; Data collection: Samuel Oluwaseun Olojede, Khayakazi Mayenziwe Mthembu, Nomthandazo Magcaba, Sodiq Kolawole Lawal; Data analysis: Samuel Oluwaseun Olojede, Khayakazi Mayenziwe Mthembu and Edwin Coleridge Naidu.

Conflict of interest

The authors declared no conflicts of interest.

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