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A Study on Axillary Artery and its Branching Pattern among the Population of West Bengal, India

Sudeshna Majumdar[1,*], Santanu Bhattacharya[1], Arpita Chatterjee[2], Hasi Dasgupta[3], Kalyan Bhattacharya[4]

[1] Department of Anatomy, Calcutta National Medical College, 32, Gorachand Road, Kolkata- 700014, West Bengal, India
[2] Department of Anatomy, College of Medicine and Sagore Dutta Hospital, 578, B.T. Road, Kamarhati, Kolkata -700058; West Bengal, India
[3] Department of Anatomy, NRS Medical College,138, A.J.C.Bose Road, Kolkata -700014, West Bengal, India
[4] Department of Anatomy, R.G.Kar Medical College, 1, Khudiram Bose Sarani, Kolkata-700004,West Bengal, India

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Summary

Variations in the branching pattern of the axillary artery have paramount importance among anatomists, surgeons and radiologists. A study was conducted on this topic in Kolkata, among the people of West Bengal, a state of India. The upper limbs of 70 cadavers were dissected bilaterally at the Department of Anatomy, Calcutta National Medical College, Kolkata, between 2008 and 2011. Among the study population, 52 cadavers (74.3%) were male and the rest were female, with average age 62.01 years (standard deviation = 6.58) and average height 1.59 meter (standard deviation = 0.096) respectively. The mean length of the axillary artery was 10.15 cm (standard deviation = 1.056). The superior thoracic, thoracoacromial and subscapular arteries were found to be constant branches of the axillary artery while the other branches showed considerable variations. Among those constant branches a high, significant correlation was found between the distance of origin of thoracoacromial artery from the outer border of the 1st rib and the length of the axillary artery, for the right and respectively the left upper limb of male cadavers. In females it showed a moderate, albeit significant correlation only. Similarly, the length of the axillary artery established a moderate correlation with the distance of origin of the superior thoracic and of the subscapular arteries on the right side of female cadavers. No other significant correlation was obtained.

Key words

Superior thoracic artery; lateral thoracic artery; thoracoacromial artery; subscapular artery; anterior circumflex humeral artery; posterior circumflex humeral artery.

Introduction

The normal and variant anatomy of the axillary artery and its branches has pragmatic importance for surgeons and anatomists for accurate diagnosis of different clinical conditions and surgical procedures (Daimi et al., 2010). The axillary artery is the continuation of the subclavian artery. It begins at the outer border of the first rib and ends at the lower border of the teres major muscle where it becomes the bra-

*Corresponding author. E-mail: sudeshnamajumdar.2007@rediffmail.com.

chial artery. Pectoralis minor muscle crosses it and divides it into three parts which are proximal, posterior and distal to the muscle. The common branches are superior thoracic, thoracoacromial, lateral thoracic, subscapular, anterior and posterior circumflex humeral arteries. The superior thoracic artery is a small vessel which arises from the first part of the axillary artery near the lower border of subclavius muscle. It sometimes arises from the thoracoacromial artery. The thoracoacromial artery is a short branch which arises from the second part of the axillary artery. It is at first overlapped by the pectoralis minor muscle. It has the following branches: deltoid, pectoral, acromial and clavicular. The lateral thoracic artery arises from the 2nd part of axillary artery. It follows the lateral border of the pectoralis minor muscle as far distally as the fifth intercostals space (Standring et al., 2008). The subscapular artery is the largest branch of the axillary artery. It usually arises from the third part of the axillary artery at the distal border of the subscapularis. It follows the inferior border of that muscle and anastomoses with the lateral thoracic, intercostal and the deep branch of the transverse cervical arteries. Approximately 4 cm from its origin, the subscapular artery divides into circumflex scapular artery and thoracodorsal artery. The circumflex scapular artery curves backwards around the lateral border of the scapula and traverses a triangular space between the subscapularis muscle above, teres major below and the long head of triceps laterally. The thoracodorsal artery follows the lateral margin of scapula, posterior to the lateral thoracic artery between the latissimus dorsi and the serratus anterior muscles. The anterior circumflex humeral artery arises from the third part of the axillary artery at the distal border of the subscapularis muscle. It runs horizontally to reach the surgical neck of the humerus. The posterior circumflex humeral artery is larger than the anterior. It arises from the third part of the axillary artery at the distal border of the subscapularis muscle and runs back with the axillary nerve through the quadrangular space (Standring et al., 2008).

The alar thoracic artery is a very inconstant branch arising from the second part of the axillary artery. It supplies fascia and lymph nodes of the axilla (Standring et al., 2008). In addition to these branches, a superior subscapular artery was described earlier in 86% instances (Huelke, 1959). In 1928, DeGaris and Swartley found 5-11 branches of the axillary artery in a study of 512 axillary arteries, with variation in site and pattern of origin.

This work has been designed to obtain data on the prevalence and pattern of variations from the native population of West Bengal, a state of India. Though several isolated case reports have been presented earlier, no comprehensive analytical study has been so far undertaken in this population. So, the aim of our study is to find out the branching pattern of axillary artery among this population with respect to the points of origin, relation to the axillary artery and different variations of these branches.

Materials and Methods

A total of 70 embalmed adult cadavers, 52 males (74.3%) and 18 females (25.7%), were dissected bilaterally in the Department of Anatomy, Calcutta National Medical College, Kolkata, during a study period of October 2008 to September 2011. The departmental records were used to assess their residence. Dissection was carried out carefully to expose the axillary artery and its different branches. Mean age and height of the cadavers were 62.01 years, with standard deviation 6.58 years (range: 50-73 years), and 1.59 meter, with standard deviation 0.10 meter (range: 1.3-1.8 meter), respectively.

To measure the length of the axillary artery, the upper limb was kept abducted (90 degree) and the measure was taken from the midpoint of the width of the artery where it crossed the outer border of first rib to midpoint of the width of the artery where it crossed the lower border of teres major muscle. A thread was kept all along the artery length and was marked at the two points said above. It was then lifted from the dissection area and spread along a graduated metric scale to measure the length.

The origin of each branch of axillary artery was noted. The distance between the proximal point of the main artery and point of origin of the branch was measured as suggested by Adachi (1928), i.e. from the beginning of the trunk to the distal angle of the branch, because the distal angle is acute and offers a definite point while the proximal angle is open and less well defined.

Different variations were noted and photographs were taken. Collected data was tabulated in Excel (Microsoft Corporation, Redmond, WA) spread sheet and was analyzed by Epi-info 3.5.1 software (CDC, Atlanta, GA). P = 0.05 was assumed as significance limit. For correlation coefficients, $|r| > 0{,}29$ was assumed as significant.

To take photographs for figure, the preparations were brush stained with acrylic colors.

Results and analysis

The most common length of axillary artery was 9.5 cm (10.7% of the cases), with an average length and standard deviation of 10.15 cm and 1.06 cm respectively (range: 8-13.3 cm).

Table 1 shows length of the axillary artery according to sex and side. $P < 0.05$ indicates that the result is statistically significant. No significant difference in mean length of axillary artery was found between males and females nor between right and left side.

The number of branches of axillary artery varied from 5 to 7 and the commonest number was 6 (94.3%). Out of 140 upper limbs, variations were found in 7 cases (5%) where the branches showed unusual patterns of origin. Interestingly no case of

Table 1 – Mean length along with standard deviation, minimum, maximum, median and mode values (cm) of the axillary artery according to sex and side. Student's *t* test for unpaired values, with two tails, was used for statistical analysis.

	Mean (cm)	Standard Deviation (SD) (cm)	Minimum (cm)	Maximum (cm)	Median (cm)	Mode (cm)	Significance
Male (n=104)	10.1317	1.0395	8	13.3	10	9.5	not significant
Female (n=36)	10.1972	1.1155	8	13.3	10.05	10.2	
Right (n=70)	10.19	1.1194	8	13.3	10	9.5	not significant
Left (n=70)	10.1071	0.9947	8	13.3	10	10.2	

bilateral variation was found. Among the males, four cases of variations (7.7%) were observed on the right side and one on the left side (1.9%). The other two cases of variations were found on the left side of the female cadavers (11.11%).

The following variations were observed in the present study:

Case 1: On the right side of a 65 year old male cadaver, circumflex scapular artery arose from the third part of the axillary artery separately from other branches. Subscapular artery after arising from the second part of the axillary artery divided into lateral thoracic and thoracodorsal artery. Two unnamed muscular branches were found arising from the second part of the axillary artery and supply adjacent pectoral and intercostal muscles (Fig. 1).

Case 2: On the right side of a 70 year old male cadaver, posterior circumflex humeral artery branched out from the subscapular artery about 0.8 cm distal to the origin of the latter artery from the third part of the axillary artery (Fig. 2).

Case 3: A similar anomaly was observed on the left side of a 62 year female cadaver, where posterior circumflex humeral artery branched out from the subscapular artery about 1.2cm distal to its origin from the third part of the axillary artery. In addition, a superficial artery was observed running subcutaneously in the base of axilla and on reaching the thoracic wall it dissipated in small branches in the superficial layers. That superficial artery arose from the third part of the axillary artery and hence was considered as an unusual variant of alar thoracic artery (Fig. 3).

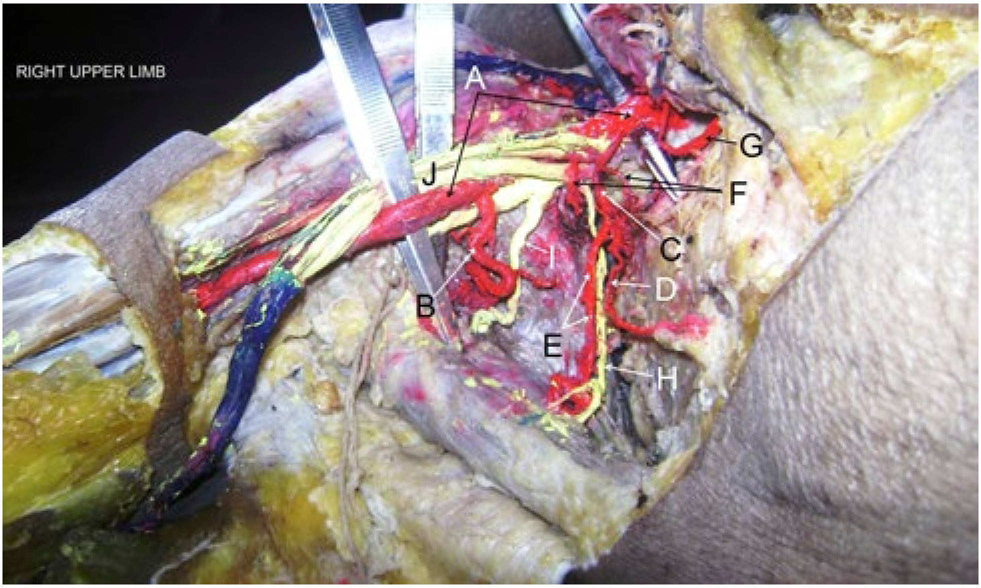

Figure 1 – Origin of circumflex scapular artery from the third part of the axillary artery and beginning of lateral thoracic artery from the subscapular artery that branched from the second part of the axillary artery along with two unnamed muscular branches (right side). A: axillary artery; B: circumflex scapular artery; C: subscapular artery; D: lateral thoracic artery; E: thoracodorsal artery; F: two muscular arteries; G: superior thoracic artery; H: nerve to latissimus dorsi; I: lower subscapular nerve; J: different cords of brachial plexus.

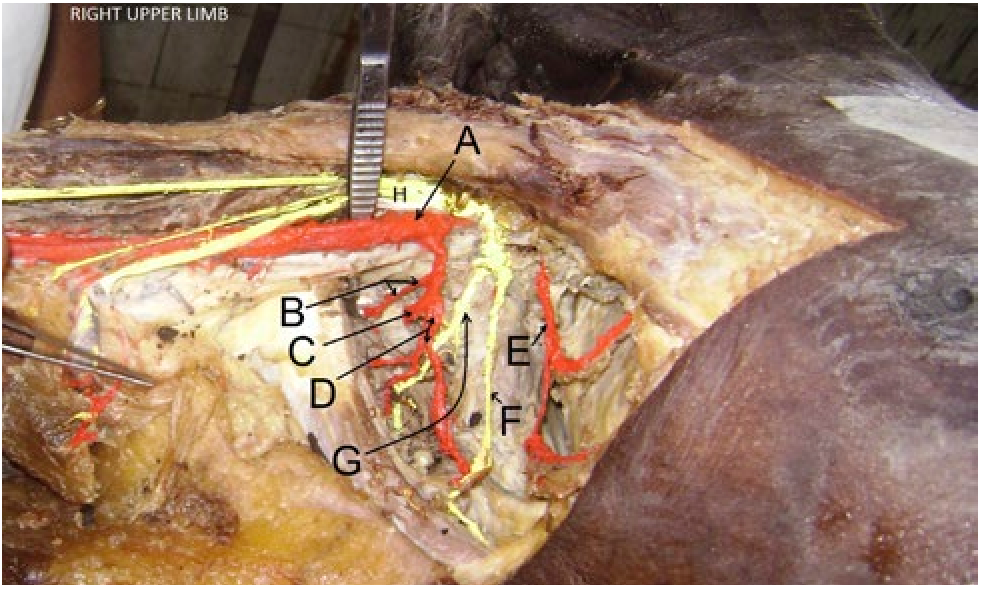

Figure 2 – Origin of posterior circumflex humeral artery from the subscapular artery (right side). A: axillary artery; B: posterior circumflex humeral artery; C: circumflex scapular artery; D: thoracodorsal artery; E: lateral thoracic artery; F: nerve to latissimus dorsi; G: lower subscapular nerve; H: different cords of brachial plexus.

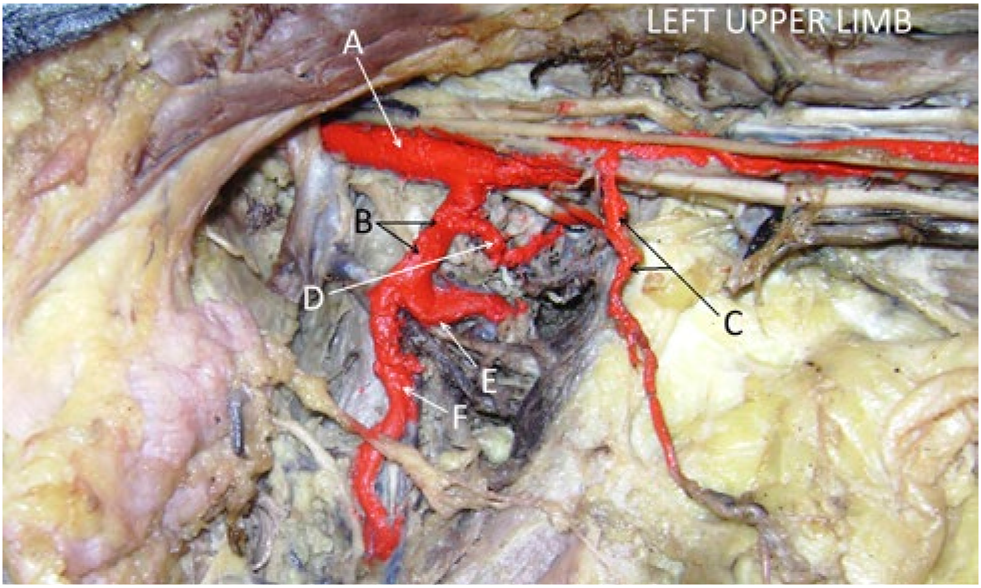

Figure 3 – Origin of posterior circumflex humeral artery from the subscapular artery and of an alar thoracic branch from the third part of the axillary artery (left side). A: axillary artery; B: subscapular artery; C: alar thoracic artery; D: posterior circumflex humeral artery; E: circumflex scapular artery; F: thoracodorsal artery.

Case 4: On the left side of a 62 year male, an alar thoracic artery branched out from the third part of the axillary artery in a similar fashion as above described. Soon it divided into branches and distributed as described for case 3 (Fig. 4).

Case 5: An anomalous origin of lateral thoracic artery was found on the right side of a 72 year old male cadaver where the artery branched out from the subscapular artery in spite of its normal origin from the second part of the axillary artery (Fig. 5).

Case 6: On the left side of a 57 year old female cadaver the lateral thoracic artery was absent and the second part of the axillary artery gave origin to thoracoacromial artery and an unnamed muscular branch which supplied the pectoralis minor muscle from the deep surface (Fig. 6).

Case 7: On the right side of a 58 year old male cadaver a common circumflex humeral artery arose from third part of the axillary artery and subsequently divided into anterior and posterior circumflex humeral branches. An unnamed muscular branch was also found to arise from the same part of the axillary artery and supplied the muscles of posterior wall of axilla (Fig. 7).

In this study superior thoracic, thoracoacromial and subscapular arteries were found in all 140 upper limbs arising from the axillary artery. So, they can be considered as the constant branches of the axillary artery. In all cases superior thoracic and thoracoacromial arteries were arising from the first and second parts of the axillary artery. Subscapular artery branched out from the third part of the same artery in all cases except one (Case 1). Lateral thoracic, anterior and posterior circumflex humer-

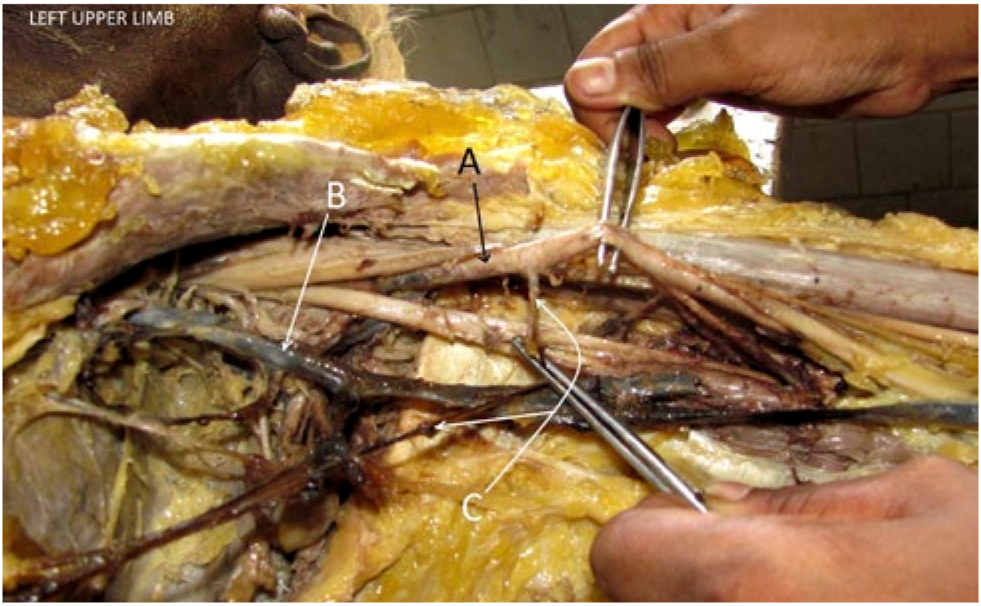

Figure 4 – Origin of alar thoracic artery from the third part of the axillary artery (left side). A: axillary artery; B: axillary vein; C: alar thoracic artery.

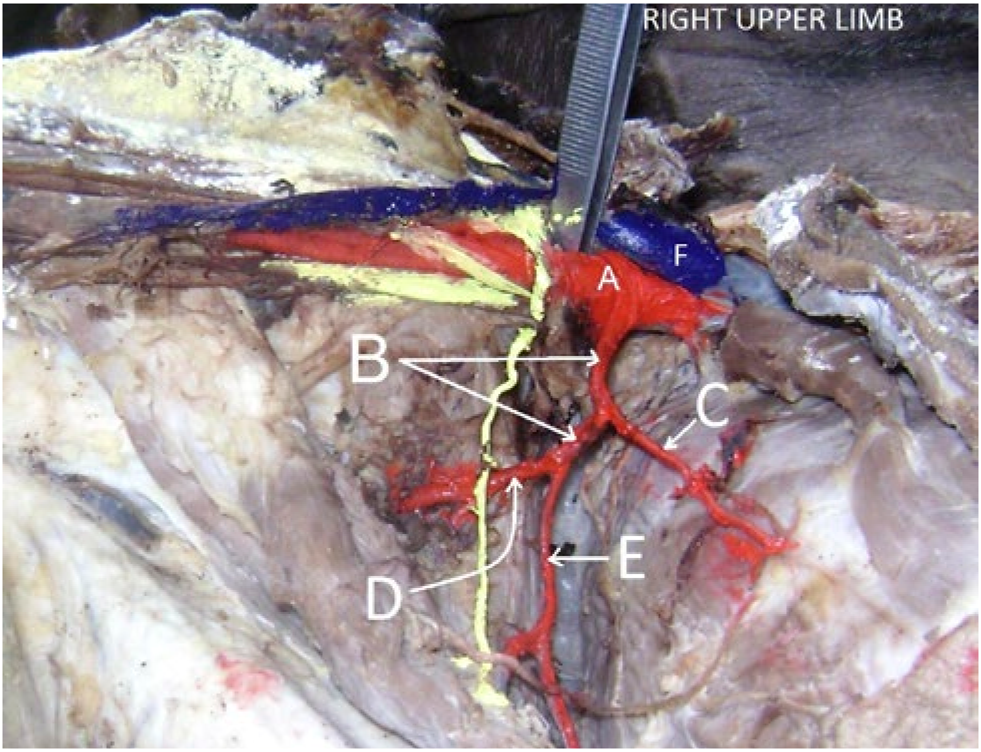

Figure 5 – Origin of lateral thoracic artery from the subscapular artery (right side). A: axillary artery; B: subscapular artery; C: lateral thoracic artery; D: circumflex scapular artery; E: thoracodorsal artery; F: axillary vein.

al arteries arising separately from the axillary artery were found in 137 (97.9%), 139 (99.3%) and 137 (97.9%) cases respectively. Among those cases, lateral thoracic artery arose from the second part and anterior and posterior circumflex humeral arteries branched out from the third part of the axillary artery as usual. Moreover, unnamed muscular branches were found on the right side of two male cadavers (3.85%) and on the left side of one female cadaver (5.56%) (Figs. 1, 6 and 7).

The distances of origin of different branches of the axillary artery from the outer border of first rib are reported in Table 2.

Table 3 reports the linear regression equations for prediction of the length of axillary artery from the subject height and age and from the distance of origin of the constant branches from the beginning of the axillary artery at the outer border of first rib. Table III also reports the corresponding coefficients of determination.

The linear correlation coefficient r measures the strength and the direction of a linear relationship between two variables. The value of r is such that $-1 < r < +1$. The + and – signs are used for positive linear correlations and negative linear correlations, respectively.

$r \geq +0.8$ or ≤ -0.8 indicates strong correlation.

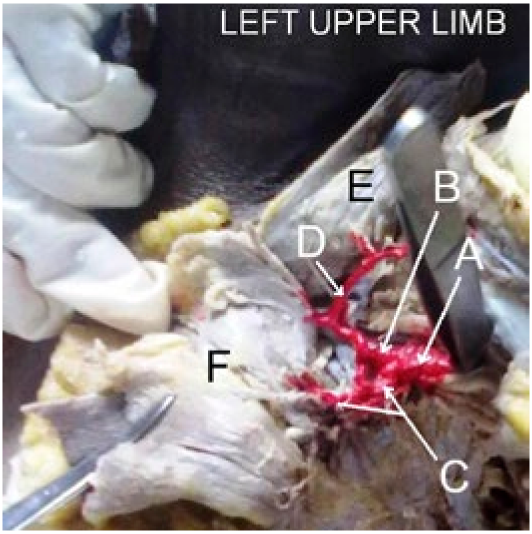

Figure 6 – An unnamed muscular branch supplying pectoral muscles in a case where the lateral thoracic artery was absent (left side). A: axillary artery; B: thoracoacromial artery; C: an unnamed muscular branch; D: pectoral branch of thoracoacromial artery; E: pectoralis major; F: pectoralis minor.

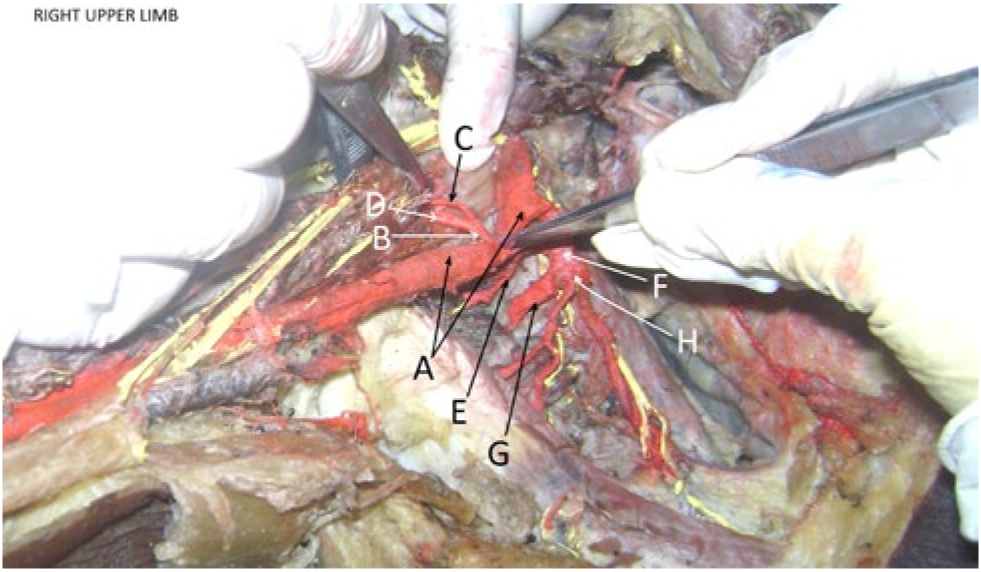

Figure 7 – Origin of anterior and posterior circumflex humeral arteries as a common trunk, and of an unnamed muscular branch from the third part of the axillary artery. A: axillary artery; B: common trunk to give rise to the anterior and posterior circumflex humeral arteries; C: anterior circumflex humeral artery; D: posterior circumflex humeral artery; E: unnamed muscular branch; F: subscapular artery; G: circumflex scapular artery; H: thoracodorsal artery.

Table 2 – Average distances of origin of different branches of axillary artery from the outer border of first rib along with standard deviation, minimum, maximum, median and mode (cm).

Branches of axillary artery	Mean (cm)	Standard Deviation (cm)	Minimum (cm)	Maximum (cm)	Median (cm)	Mode (cm)
Superior thoracic artery (n=140)	2.5193	0.5472	0.9	3.1	2.6	2.5
Thoraco-acromial artery(n=140)	3.1950	0.6676	2.0	4.8	3.1	2.5
Subscapular artery (n=140)	7.4679	0.9823	4.8	10.8	7.5	7.5
Lateral thoracic artery (n=137)	3.7336	0.6999	2.5	6.0	3.7	3.8
Anterior circumflex arteries (n=139)	8.1906	1.2102	4.9	11.2	8.1	8.0
Posterior circumflex arteries (n=137)	8.6153	1.0861	5.7	11.8	8.4	8.4

Table 3 – Linear regression equations for prediction of axillary artery length from height, age and distance of origin of its constant branches from the outer border of first rib (beginning of the axillary artery); n = 140.

Parameters	Length of axillary artery (cm)	
With age (years)	9.422+ 0.012×age	$r^2 = 0.01$
With height (m)	7.742+1.515×height	$r^2 = 0.02$
With origin of superior thoracic artery from outer border of first rib (a)	8.865+0.510×(a)	$r^2 = 0.07$
With origin of thoraco-acromial artery from outer border of first rib (b)	6.159+1.249×(b)	$r^2 = 0.62$
With origin of subscapular artery from outer border of first rib (c)	7.095+0.409×(c)	$r^2 = 0.14$

r = - 0.79 to -0.3 or +0.3 to +0.79 indicates moderate correlation.
r ≤ +0.29 or ≥ -0.29 indicates weak correlation.
r = 0 indicates no correlation.

The correlation coefficients between the length of axillary artery and height and age were 0.14 and 0.1 respectively, *i.e.* insignificant.

Lateral thoracic and circumflex scapular arteries showed considerable variations in their origin and sometimes were absent at all. Therefore, in the present study, inconsistent branches were not considered as good parameters for predicting the length of the axillary artery and we tried to find out a correlation between the length of axillary artery and distances of origin of only its constant branches from the outer border of first rib (beginning of the axillary artery). The correlation coefficients for superior thoracic, thoracoacromial and subscapular arteries were 0.26, 0.8 and 0.37 respectively. So, a high correlation was found with the distance of origin of thoracoacromial artery. No significant correlation was found with the origin of superior thoracic artery, while moderate correlation was obtained with that of subscapular artery.

Table 4 – Correlation coefficients (r) between the length of the axillary artery and the distance of origin of its constant branches from the outer border of first rib among males and females as well as between right and left sides; n = 140.

Branches of axillary artery	Gender		Side	
	Male (n=52)	**Female(n=18)**	**Right(n=70)**	**Left (n=70)**
Superior thoracic artery	0.25	0.32	0.32	0.2
Thoracoacromial artery	0.82	0.7	0.8	0.8
Subscapular artery	0.25	0.66	0.5	0.2

The coefficient of determination, r^2, gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variables. It is a measure that allows us to determine how certain one can be in making predictions from a certain model/graph. The coefficient of determination is the ratio of the explained variation to the total variation. The coefficient of determination is such that $0 < r^2 < 1$ and denotes the strength of the linear association between x and y. The coefficient of determination represents the percent of the data that is closest to the line of best fit. For example, if $r = 0.922$, then $r^2 = 0.850$, which means that 85% of the total variation in y can be explained by the linear relationship between x and y (as described by the regression equation). The other 15% of the total variation of y remains unexplained. Among all cases, r^2 was highest for thoracoacromial artery.

We then tried to find out the correlation coefficient between the length of axillary artery and the distance of origin of its constant branches, between males and females and between right and left sides separately (Table 4).

Among males, a strong correlation was obtained for thoracoacromial artery but a weak correlation was found for all other branches. Among females, a moderate correlation was obtained for all branches, the highest value was for the thoracoacromial artery. Moreover, a strong correlation was established for the thoracoacromial artery on both sides. The other branches showed a moderate correlation on the right side and a weak correlation on the left side.

So, it appeared that the distance of origin of thoracoacromial artery is the best predictor for the length of the axillary artery among the all parameters in this study. Superior thoracic and subscapular arteries are relatively good predictors among the females and right sided cases only.

Discussion

The branches of axillary artery show numerous variations in number, origin and distribution (Standring et al., 2008). Therefore, only the relevant cases that have similarity with the present study are discussed here.

According to DeGaris and Swartley (1928), any branch of the axillary artery may arise proximal or distal to its usual site. Two or more of the named vessels may arise by a common stem from the axillary artery and there may be other unnamed branches. It is the lateral thoracic artery that shows variations in the maximum number of cases. The unusual branches of the axillary artery observed by those authors were the following: a) a common stem for anterior and posterior circumflex humeral arteries; b) a branch to shoulder joint and muscles of the arm; c) a branch to subscapular muscle; d) a branch to lateral thoracic wall; e) branches to shoulder joint and muscles of the arm; f) circumflex scapular and thoracodorsal arteries arising separately from axillary artery (DeGaris and Swartley, 1928).

The origin of circumflex scapular artery directly from axillary artery was also described by Khaki et al. (2011). Occasionally, the subscapular, circumflex scapular and profunda brachii arteries arise in common from the axillary artery. In that case, the branches of brachial plexus follow these common vessels instead of axillary artery (Standring et al., 2008). These findings have similarities with Cases 1, 6 and 7 of the present study where unnamed muscular branches and a common origin of anterior and posterior circumflex humeral arteries were found.

A previous study described a variety of common subscapular trunks that gave origin to different branches like circumflex scapular, thoracodorsal, anterior and posterior circumflex humeral, profunda brachii and ulnar collateral arteries (Venieratos and Lolis, 2001). Besides, origin of lateral thoracic artery from the subscapular artery was also reported in 25% cases by Trotter et al. (1930). In another study a common trunk was reported to branch out from the third part of the axillary artery and subsequently give origin to anterior and posterior circumflex humeral and subscapular arteries (Walsham, 1880). In the present study posterior circumflex humeral artery arose from subscapular artery in two cases (1.43%; Cases 2 and 3) and in common with anterior circumflex humeral artery in one case (0.7%; Case 7]. The lateral thoracic artery branched out from subscapular artery in two cases (1.43%; Cases 1 and 5) and was absent in one case also (0.7%; Case 6).

Few cases of absent lateral thoracic artery were also reported before. In such cases, sometimes that artery was replaced by lateral perforating branches of the intercostal arteries.

Occasionally, it became or gave off a direct cutaneous branch (superficial thoracic artery) which supplied the skin over the lateral border of the pectoralis major (Patnaik et al., 2000; Standring et al., 2008). In the present study, the alar thoracic artery was found on the left side of one male (1.9%) and one female cadaver (5.6%), arising from the third part of the axillary artery (Cases 3 and 4). A rare case of bilateral variation of alar thoracic artery was reported earlier where on the right side this artery originated from the third part of the axillary artery and on the opposite side from the first one centimeter of radial artery arising directly from the left sided axillary artery together with the left brachial artery (Rusu, 2005).

Embryologically, such anomalous branching pattern may represent persisting branches of the capillary plexus of the developing limb buds. The seventh cervical segmental artery gives rise to axillary artery and any deviation of it during development results in unusual branching pattern (Wollard, 1922). Normally, in embryos of 11 mm length, the seventh cervical intersegmental artery enlarges and becomes the dominant vessel of axilla. C6, C7 and T1 segmental arteries and most of the longitudinal anastomoses which link up the intersegmental arteries degenerate slowly. The numerous alternatives that exist during the formation of upper limb vessels seem to be responsible for anomalous arterial branching patterns (Saralaya et al., 2008).

The discussion of the various branching pattern of the axillary artery however cannot be accomplished without describing the sites of origin of different branches and their strength of correlation with the mother artery. To the best of our knowledge only a single study was performed before by Patnaik et al. (2000), where the average length of axillary artery was found to be 10.17 cm and the mean distance of origin of superior thoracic, thoracoacromial, lateral thoracic, subscapular, anterior and posterior circumflex humeral arteries from the outer border of the first rib were 1.46 cm, 2.86 cm, 3.15 cm, 6.69 cm, 7.9 cm and 7.77 cm respectively. But the study did not provide any information about the correlations among the axillary artery and its different branches. However, in comparison to the previous study, the present work presents a shorter length of axillary artery with longer distances of origin of all of its branches among the West Bengal population of India.

Conclusion

The knowledge of axillary artery and its different branches is necessary for general and vascular surgeons considering the frequency of procedures performed in this region (Saralaya et al., 2008). The present study not only describes different variations in the branching pattern of the axillary artery but also establishes a relation among the axillary artery and subject age and height and the distances of origin of constant branches from the point of beginning of the axillary artery. If one variable is known, the other one can be calculated. As the axillary artery and its branches show considerable racial variations, further study in future is needed to confirm of the findings of the present study.

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