SSR Institute of International Journal of Life Sciences
ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Gawali et al., 2024
DOI: 10.21276/SSR-IIJLS.2024.10.5.8

Original Article

open access

Assessment of Brachial Artery Dimensions and Variations: A Comprehensive Study

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Received: 04 Mar 2024/ Revised: 19 May 2024/ Accepted: 22 Aug 2024

ABSTRACT

Background- The brachial artery is a vital arterial conduit in the upper limb with significant clinical implications. Understanding its anatomical variations and measurements is essential for surgical interventions and diagnostic procedures. This study aims to investigate the anatomical characteristics of the brachial artery and their relevance to clinical practice.

Methods- This anatomical study involved 60 embalmed cadavers (56 males and 4 females) aged 18 to 65 years. Dissection was performed to expose the brachial artery from its origin at the axillary artery to its bifurcation into the radial and ulnar arteries. The lengths and diameters of the brachial artery were measured, and variations in branching patterns were documented.

Results- The mean brachial artery length was 27.03±2.18 cm on the left side and 26.66±3.83 cm on the right. The majority of lengths fell within the range of 20 to 29.9 cm. Notably, 14 limbs (11.7%) exhibited anatomical variations, including superficial brachial arteries and common trunks for the profunda brachii and superior ulnar collateral arteries. The mean diameter at the origin was 4.40 mm on the right and 4.29 mm on the left, decreasing to 4.07 mm and 3.98 mm at termination, respectively.

Conclusion- The study highlights significant variability in the length and branching patterns of the brachial artery, emphasizing its clinical relevance. These findings contribute to the existing anatomical knowledge and may aid in improving surgical outcomes and diagnostic accuracy in upper limb procedures. Further research is warranted to explore these variations in diverse populations.

Key-words: Brachial Artery, Chronic renal failure, Intra-aortic balloon, Interepicondylar line, Profunda brachii

INTRODUCTION

The brachial artery is a crucial arterial conduit from a clinical perspective, and understanding its branching patterns and variations is essential for healthcare professionals such as surgeons, orthopedicians, physicians, radiologists, and interventionists. This anatomical knowledge can lead to new diagnostic and therapeutic approaches. Notably, the percutaneous insertion of an intra-aortic balloon (IAB) via the brachial artery has demonstrated effectiveness and safety in patients with vascular disease who are undergoing coronary artery bypass surgery [1]. The radial artery is currently recognized as the preferred site for vascular access during coronary angiography and angioplasty [2]. It is essential to accurately confirm the anatomy of the artery to minimize the risk of iatrogenic injuries. An abnormal, tortuous brachial artery may be mistakenly identified as the basilic vein during cannulation, underscoring the importance of a thorough anatomical assessment before the procedure [3].

The brachial artery's role in predicting late in-stent coronary restenosis (ISR) is significant, as studies have demonstrated that impairment of flow-mediated dilation (FMD) in the brachial artery correlates with late diameter loss and ISR following stenting in native coronary

How to cite this article
Gawali R, Sande V, Natarajan M. Assessment of Brachial Artery Dimensions and Variations: A Comprehensive Study. SSR Inst Int J Life Sci., 2024; 10(5): 6167-6173.

Access this article online
https://iijls.com/

DOI: 10.21276/SSR-IIJLS.2024.10.5.8

arteries. This association persists independently of clinical and angiographic variables typically linked to ISR. Consequently, it suggests that endothelial vasomotor function within a systemic artery may be critically connected to the pathobiological processes underlying ISR. Furthermore, previous research indicates that endothelial-derived nitric oxide is crucial in suppressing smooth muscle proliferation inhibiting intimal hyperplasia after vascular injury, as evidenced by animal model studies [4,5].

Anatomists and surgeons have paid much attention to the differences in the origin and course of the main arteries in the superior extremities. Understanding the relationships and pathways of these arteries, along with their variation patterns, is crucial for reparative surgery involving the arm, forearm, and hand. This knowledge is essential for certain surgical procedures on the superior extremities, as it can greatly influence surgical outcomes and patient safety [6].

The brachial artery is preferred for creating an autogenous fistula in treating chronic renal failure (CRF) for dialysis. This method is favoured because such fistulas have a longer lifespan and require less maintenance than other access options. Specifically, the brachial artery-brachial vein fistula has been identified as a feasible option for hemodialysis access, making it an important consideration in managing patients requiring dialysis [7]. The present study is undertaken to assess brachial artery dimensions and variations.

MATERIALS AND METHODS

Study Design- Over three years i.e. 2011 to 2013, this anatomical cadaveric study was conducted at the Department of Anatomy, Seth G. S. Medical College and K.E.M. Hospital, Mumbai. A total of 60 cadavers were utilized for this anatomical study. Out of the 60 cadavers used in this study, 56 were male and four were female. All the cadavers ranged between the age group of 18-65 years and were obtained from a teaching institute and a tertiary care hospital.

Inclusion criteria- Cadavers that showed no evidence of previous surgical interventions in the upper limb were included in the study.

Exclusion criteria- Cadavers with any visible signs of trauma or deformity in the upper limb and that had undergone previous surgeries affecting the brachial artery or its branches were excluded from the study.

Dissection Procedure- The dissection was performed by first incision and reflecting the skin to expose the underlying structures. The arm and front of the forearm, which reach from the lower border of the teres major muscle to the cubital fossa, were then exposed after the removal of both the superficial and deep fascia. To make the brachial artery easier to reach, the bicipital aponeurosis was cut vertically. One important anatomical landmark that indicates the origin of the brachial artery is the bottom border of the teres major muscle. After that, the brachial artery was followed as far distally as the cubital fossa, including its branches, and as close as possible to its termination at the level where it continues to join the axillary artery. Many significant anatomical landmarks were revealed during this dissection, including the lateral and medial epicondyles of the humerus and, finally, the brachial artery's terminus.

Measurement Parameters- The brachial artery was meticulously measured using a divider, measuring scale, and thread to obtain various anatomical parameters. The total length of the brachial artery was recorded from its origin at the axillary artery to its termination at the bifurcation into the radial and ulnar arteries. Additionally, measurements were taken from the origin of the brachial artery to the interepicondylar line (ICL), which serves as a crucial landmark for elbow anatomy. The segment from the ICL to the termination point of the brachial artery was also documented. Furthermore, distances were measured along the interepicondylar line: specifically, between the medial margin of the brachial artery and the medial epicondyle of the humerus, as well as between the lateral margin of the brachial artery and the lateral epicondyle of the humerus. Another important measurement included determining the distance from the origin of the brachial artery to that of its major branch, the profunda brachii artery. Lastly, both brachial artery diameters were assessed at their origin and termination to provide insights into their anatomical variations.

Statistical Analysis- The collected data was systematically recorded and analyzed for comparison and correlation. The analysis included calculating the measurements' range, mean, and standard deviation. The mean was computed using the appropriate statistical formula, and the standard deviation (SD) was determined to assess the variability of the measurements.

Ethical Approval- Ethical approval for the study was obtained from the institutional ethical committee.

RESULTS

The study involved 60 embalmed cadavers, comprising 56 males and 4 females, all aged between 18 and 65 years. The analysis of the brachial artery revealed that the mean length was 26.66 cm on the right side and 27.03 cm on the left side. The right brachial artery exhibited a range from a minimum of 3 cm to a maximum of 31 cm, while the left side ranged from 22.5 cm to 30.7 cm. Notably, the brachial artery was absent on the right side in one cadaver. In another, it was very short, dividing into the radial and ulnar arteries in the upper third of the arm.

On the right side, the length of the brachial artery indicates that 55 out of 59 cases (93.22%) fell within the range of 20 to 29.9 cm, while on the left side, 53 out of 60 cases (88.33%) were also within this range. Notably, there were no cases on either side with lengths between 10-19.9 cm, and only one on the right side measured between 1-1.9 cm. Additionally, three cases on the right side and seven on the left side had 30 cm or greater lengths. The data highlights a predominance of brachial artery lengths between 20 and 29.9 cm on both sides.

Fig. 1 details the lengths of the brachial artery from its origin to ICL. The mean length was 24.82 cm on the right side and 24.86 cm on the left side, with ranges of 20 cm to 29.1 cm and 20 cm to 29.2 cm, respectively. Regarding distribution, on the right side, 50% of cases (29 out of 58) had lengths between 23 and 25.9 cm, while on the left side, 53.33% of cases (32 out of 60) fell within the same range. Overall, the data indicates a consistent length of the brachial artery from its origin to the ICL across both sides.

While determining the lengths of the brachial artery from ICL to its termination, it was observed that the average length was 2.25 cm on the right side and 2.15 cm on the left side, with ranges of 1 cm to 3.5 cm and 1 cm to 3.4 cm, respectively. On the right side, 36.20% of cases (21 out of 58) measured between 1 and 1.9 cm, while 37.93% (22 cases) fell within the 2 to 2.9 cm range. In contrast, on the left side, 33.33% of cases (20 out of 60) were in the 1 to 1.9 cm range, and 45% (27 cases) were between 2 and 2.9 cm. This data highlights a slight variation in the lengths of the brachial artery from the ICL to termination between the two sides.

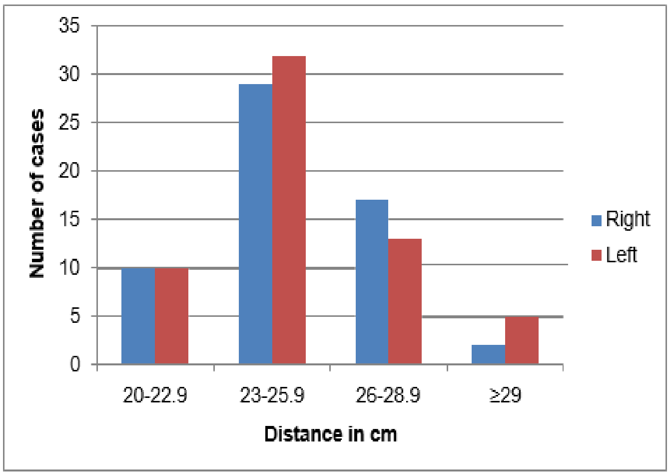

Fig. 1: Length of the brachial artery from its origin to ICL

Fig. 2A provides data on the distance between the medial margin of the brachial artery and the medial epicondyle of the humerus. The average distance was 4.24 cm on the right side and 4.21 cm on the left side, with ranges of 3.6 to 4.9 cm and 3.1 to 4.8 cm, respectively. Notably, 67.24% of cases on the right side (39 out of 58) had distances between 4.1 and 4.5 cm, while 63.33% of cases on the left (38 out of 60) fell within the same range, indicating a consistent measurement across both sides.

However, Fig. 2B presents the distances between the brachial artery's lateral margin and the humerus's lateral epicondyle. The average distance was consistently measured at 3.29 cm on both the right and left sides, with ranges of 2.2 to 4.4 cm on the right and 2.2 to 4.6 cm on the left. On the right side, 67.24% of cases (39 out of 58) had distances between 3 and 3.9 cm, while 66.66% of cases (40 out of 60) on the left side fell within the same range, indicating similar measurements across both sides.

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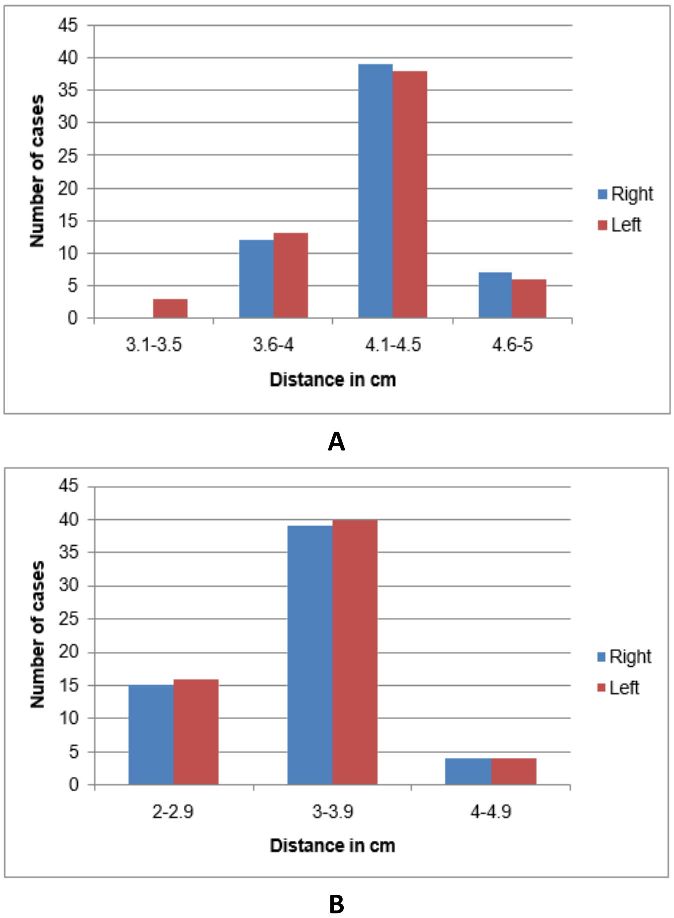

Fig. 2: Distance between **A.** Medial margin of the brachial artery and the medial epicondyle and **B.** lateral margin of the brachial arteryand the lateral epicondyle of the humerus along ICL.

The diameter of the brachial artery at its origin showed an average diameter of 4.40 mm on the right side and 4.29 mm on the left side. The diameter ranged from 3.5 to 5.5 mm on the right and 3.5 to 5 mm on the left. On the right side, 40.67% of cases (24 out of 59) had diameters between 4.1 and 4.5 mm, while 33.33% of cases on the left side fell within the 4.6 to 5 mm range, indicating slight variations in measurements between the two sides (Table 1). On the other hand, the average diameter of the brachial artery at its termination was 3.98 mm on the left and 4.07 mm on the right. The diameter ranged from 3.1 to 5 mm on the right and from 3.1 to 4.7 mm on the left. On the right side, 54.23% of cases (32 out of 59) had diameters between 4 and 4.9 mm. In comparison, 51.66% of cases on the left side fell within the same range (Table 2), indicating a similar distribution of measurements at the artery's termination across both sides.

Table 1: Diameter of the brachial artery at its origin.

Range (mm)	No. of caseson the right side (%)	No. of caseson the left side (%)
3.5-4	12 (20.33)	16 (26.66)
4.1-4.5	24 (40.67)	24 (40)
4.6-5	20 (33.89)	20 (33.33)
5.1-5.5	3 (5.08)	0 (0)
Total	59 (100)	60 (100)

Table 2: Diameter of the brachial artery at its termination.

Range (mm)	No. of caseson the right side (%)	No. of caseson the left side (%)
3-3.9	25 (42.37)	29 (48.33)
4-4.9	32 (54.23)	31 (51.66)
≥4	2 (3.38)	0 (0)
Total	59 (100)	60 (100)

In a study of 120 limbs, variations in the branching pattern of the brachial artery were observed in 14 cases (11.7%). Among these, 3 limbs (21.4%) exhibited a superficial brachial artery (SBA), while 1 limb (7.1%) had an absent brachial artery (AbBA). Additionally, 2 limbs (14.3%) presented a common trunk (CT) for the profunda brachii artery (PBA) and the superior ulnar collateral artery (SUCA). There was also 1 limb (7.1%) with a high bifurcation of the brachial artery (HBBA), 4 limbs (28.6%) with a superficial brachioradial artery (SBRA), and 2 limbs (14.3%) with a superficial brachioulnar artery (SBUA). Lastly, 1 limb (7.1%) showed a trifurcation where the brachial artery terminated into the radial recurrent, radial, and ulnar arteries (Table 3).

Table 3: Number of differences in the brachial artery's branching pattern.

Variations	Number of limbs	Percentage (%)
AbBA	1	7.1
CT	2	14.3
HBBA	1	7.1

SBA	3	21.4
SBRA	4	28.6
SBUA	2	14.3
Trifurcation	1	7.1
Total	14	100

AbBA- Absent brachial artery, CT- Common trunk, HBBA- Higher bifurcation of brachial artery, SBA- Superficial brachial artery, SBRA- Superficial brachial artery, SBRA- Superficial brachioradial artery, SBUA- Superficial brachioulnar artery

DISCUSSION

The present study on the length of the brachial artery involved 60 cadavers and yielded significant findings compared to previous research. The brachial artery's mean length was 26.66±3.83 cm on the right side and 27.03±2.18 cm on the left side. This is notably higher than the findings of Gupta *et al.*, who reported mean lengths of 22.33 cm on the right and 22.25 cm on the left from 20 cadavers [7]. Patnaik *et al.* [8] observed a mean length of 26.29 cm, comparable to the present study's results. Still, they noted bifurcation occurring at an average distance of 2.99 cm distal to the interepicondylar line. In contrast, the present study found the mean length from the origin to the interepicondylar line to be 24.82±2.17 cm on the right and 24.86±2.24 cm on the left, with the length from the interepicondylar line to termination measuring 2.25±0.72 cm on the right and 2.15±0.67 cm on the left.

Bidarkotimath *et al.* reported lengths of 23±8.64 cm in males and 22.65±0.77 cm in females [9], which are lower than the present study's findings. Chauhan *et al.* [10] conducted a study on 100 upper limbs over four years. They reported an average total length of 24.56 cm, with 22.22 cm from the lower border of the teres major to the interepicondylar line and 2.34 cm from the interepicondylar line to bifurcation. The present study's results indicate a greater length of the brachial artery, highlighting the variability in anatomical measurements across different populations and studies.

In the present study, the mean distance between the medial margin (MM) of the brachial artery and the medial epicondyle (ME) of the humerus along the ICL was measured to be 4.24±0.29 cm on the right side and 4.21±0.32 cm on the left side. Notably, this specific parameter has not been previously studied in the literature, highlighting a gap in anatomical knowledge regarding this measurement. Similarly, the mean distance between the lateral margin (LM) of the brachial artery and the lateral epicondyle (LE) of the humerus was found to be 3.29±0.47 cm on the right side and 3.29±0.50 cm on the left side. Like the medial margin measurements, this parameter has also not been documented in prior studies, indicating a need for further exploration.

In this investigation, the mean diameter of the brachial artery at its origin was measured on the right side at 4.40±0.50 mm and on the left side at 4.29±0.41 mm. The mean diameters at termination were 3.98±0.43 mm on the left side and 4.07±0.48 mm on the right. When comparing these findings to previous studies, several notable observations emerge. Shoemaker *et al.* [11] reported a mean diameter of 4.2 mm for the brachial artery during dynamic exercise, indicating a similar range to the present study's findings at the origin, particularly in the active arm where slight increases in diameter were noted post-exercise.

Kullo *et al.* utilized high-resolution ultrasound and found a mean diameter of 3.71±0.70 mm [12], lower than the present study's measurements, suggesting that the brachial artery may have a larger diameter in the studied population. Chami *et al.* [13] observed varying mean diameters associated with the severity of sleep-disordered breathing, ranging from 4.32 mm to 4.56 mm. This aligns closely with the present study's findings at the origin, particularly for those with lower apnea-hypopnea indices. Additionally, Arnold *et al.* [14] noted a mean diameter of 4.07±0.10 mm in patients with congestive heart failure, consistent with the present study's termination measurements, indicating that underlying health conditions may affect the brachial artery diameter. Overall, the present study's results suggest that the brachial artery's diameter at its origin and termination is comparable to or greater than those reported in previous research, highlighting the importance of considering individual and population-specific factors when assessing vascular health.

The current study also identified brachial artery branching variations in 14 out of 120 limbs (11.7%). Notable findings included 3 limbs with a superficial brachial artery, 1 absent brachial artery, and 2 limbs with a common trunk for the profunda brachii and superior ulnar collateral arteries. Additional variations included high bifurcations and trifurcations in several limbs.

DOI: 10.21276/SSR-IIJLS.2024.10.5.8

Comparatively, previous studies have reported varying incidences of these anatomical variations. For instance, Vatsala *et al.* [15] found a superficial brachial artery in 1.9% of specimens and a common trunk for the profunda brachii and superior ulnar collateral arteries in 29.6% of cases [16]. Vandana *et al.* [17] noted trifurcation in 3.3% of specimens and high division of the brachial artery in 5% of cases. Sawant reported a high-level termination of the brachial artery in 54 specimens, with various bifurcation patterns observed in other specimens [18]. Hee-Jun *et al.* [19] found a superficial brachial artery in 24% of their dissected cadavers, while Patnaik *et al.* [20] noted variations in 26% of instances, including a trifurcation in one case.

SUMMARY

The present study identified 11.7% of limbs with brachial artery branching pattern variations. Previous studies have reported a range of variation incidences, highlighting the anatomical diversity within the brachial artery's branching patterns across different populations and studies.

CONCLUSIONS

The study of the brachial artery's anatomical variations is crucial for clinical applications, particularly in surgical and interventional procedures. The present findings underscore the importance of individualized anatomical knowledge to minimize the risk of complications during vascular access and other interventions. Additionally, understanding the brachial artery's characteristics can enhance the predictive value for conditions such as late in-stent coronary restenosis. Overall, this study contributes valuable insights into the anatomical diversity of the brachial artery, emphasizing the need for thorough anatomical assessments in clinical practice to improve patient outcomes and procedural safety.

Future research should continue exploring these variations across different populations to further refine our understanding of the clinical significance of the brachial artery.

CONTRIBUTION OF AUTHORS

Research concept- Rohan Gawali, M. Natarajan
Research design- Rohan Gawali, M. Natarajan
Supervision- M. Natarajan
Materials- Rohan Gawali, Vaibhav Sande
Data collection- Rohan Gawali, Vaibhav Sande
Data analysis and interpretation- Rohan Gawali, Vaibhav Sande
Literature search- Vaibhav Sande, Rohan Gawali
Writing article- Vaibhav Sande, Rohan Gawali
Critical review- Rohan Gawali, Vaibhav Sande
Article editing- Rohan Gawali, Vaibhav Sande
Final approval- M. Natarajan

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ISSN (O): 2581-8740 | ISSN (P): 2581-8732
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