Original Article

DOI: 10.7860/IJARS/2023/63052.2949

Morphometry of Arch of Aorta and its Branches- A Cadaveric Cross-sectional Study

Anatomy Section

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ABSTRACT

Introduction: The Arch of Aorta (AA) originates from the ascending aorta in the superior mediastinum, specifically at the level of the right 2nd costal cartilage, behind the lower half of the manubrium sterni. The AA typically gives rise to three major arteries, namely the brachiocephalic trunk, left common carotid, and left subclavian, which is the most common branching pattern.

Aim: To investigate the morphometric parameters of the AA and its branches, including the diameters, angles formed by the branches with the AA, and the distance of origin of these branches from the mid vertebral line.

Materials and Methods: This descriptive observational cross-sectional study was conducted in the Department of Anatomy at NRI Medical College, Guntur, Andhra Pradesh, India,, from June 2017 to August 2021. A total of 50 aortic arches, along with their branches, were examined from cadavers (45 males, 5 females) assigned to 1st-year MBBS students for regular dissection practicals. Measurements such as the diameter of the arch at its origin and termination, diameter of major vessels at their origin, angles made by major vessels at their origin with the convexity of the arch, and the distance of origin of major branches from the midvertebral line were recorded. Vernier calipers with an accuracy of 0.01 mm were used to measure various parameters, and angles were measured using a Goniometer. Mean and Standard Deviation (SD) were calculated for each parameter using an MS Excel sheet.

Results: The distance of origin of the brachiocephalic trunk from the midvertebral line was found to be 1.86±5.13 mm to the right of the midline, while the distance of origin of the Left Common Carotid Artery (LCCA) and Left Subclavian Artery (LSA) from the midvertebral line were +12.68±6.43 mm and +26.31±6.73 mm, respectively. The diameters of the mentioned branches at their origin were 11.22±2.29 mm, 7.39±1.49 mm, and 8.38±2.15 mm, and the angles made by these branches with the aortic arch were 89.10±18.48, 73.52±14.55, and 73.93±16.80 degrees, respectively.

Conclusion: The morphometric parameters of the AA and its branches, as observed in the present study, hold significant clinical importance and can be valuable for cardiothoracic and vascular surgeons working in this region.

Keywords: Brachiocephalic, Common carotid, Diameter, Subclavian

INTRODUCTION

The Arch of Aorta (AA) begins as a continuation of the ascending aorta in the superior mediastinum, specifically at the level of the right 2nd costal cartilage, situated behind the lower half of the manubrium sterni. It forms an upward, backward, and leftward arch across the root of the left lung, connecting the ascending and descending aortae. The arch exhibits two curvatures, one with the convexity facing upwards and the other with the convexity directed towards the left and slightly forward. Initially, it runs in front of the trachea, upwards, backwards, and to the left, terminating on the left side at the level of the 4th thoracic vertebra [1]. The three major vessels that originate from the convexity of the AA are the Brachiocephalic Trunk (BCT), LCCA, and LSA. This branching pattern is the most common, occurring in 65% of cases [1].

The AA and its major branches hold clinical significance for interventional cardiothoracic and vascular surgeons. Surgical procedures involving aortic arch replacement and reconstruction, with continuity to the aorta and supra-aortic arteries, have been evolving, offering minimal risk of ischaemic and embolic cerebral damage [2]. Interventional and hybrid approaches are emerging treatment strategies for managing AA aneurysms, albeit associated with significant morbidity and mortality [3]. Comprehensive morphometric knowledge of the AA is crucial in various stages of designing and optimising diagnostic tools like aortography. As the AA and its major branches are the sole vessels supplying blood to the head, neck, brain, and upper limbs, understanding their diameters is highly valuable in estimating blood flow. Even slight morphometric changes in the AA can have a considerable impact on blood flow [4-6].

Accurate morphometric knowledge of the AA and its major branches is paramount when performing complex surgical procedures related to the treatment of aortic aneurysms or dissections. The present study aimed to investigate the diameter of the AA and its branches at their origin, the distance of their origin from the midvertebral level, and the angles formed by the branches with the AA. Notably, there is no existing study that has encompassed all three of these parameters.

MATERIALS AND METHODS

A descriptive observational cross-sectional study was conducted in the Department of Anatomy at NRI Medical College, Guntur, Andhra Pradesh, India, from June 2017 to August 2021.

Inclusion criteria: A total of 50 aortic arches (45 males and 5 females) with their branches, obtained from embalmed human cadavers aged between 45 to 70 years, were included in the study. These cadavers were assigned to phase 1 MBBS students for routine dissection.

Exclusion criteria: Cadavers with abnormalities such as aortic aneurysms were excluded from the study.

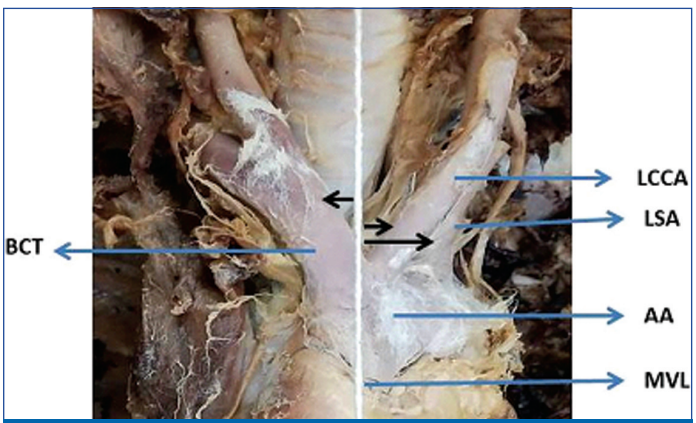
Study Procedure

During the dissection of the thoracic region, the thoracic cage was opened by cutting ribs 2nd to 9th along the mid-axillary line. The ribs, along with the sternum, were reflected onto the upper part of the anterior abdominal wall, exposing the viscera. After dissecting the fibrous pericardium, the heart, along with its major vessels, was exposed. The right and left brachiocephalic veins were gently severed, and the AA and its branches were exposed. The recorded

observations included the diameter of the arch at its origin and termination [Table/Fig-1,2], the diameter of major vessels at their origin, the angles made by the major vessels at their origin with the convexity of the arch [Table/Fig-3], and the distance of origin of major branches from the midvertebral line [Table/Fig-4]. Various parameters were measured using Vernier calipers with an accuracy of 0.01 mm, and angles were measured using a Goniometer.

[Table/Fig-1]: The measurement of diameter of Arch of Aorta (AA) at its begining using vernier calipers.
BCT: Brachicephalic trunk; LCCA: Left common carotid artery; LSA: Left subclavian artery

[Table/Fig-2]: The measurement of diameter of Brachiocephalic Trunk (BCT) at its origin as the first branch of Arch of Aorta (AA) using vernier calipers.
[Table/Fig-3]: Showing the angle made by BCT with AA. (Images from left to right)



[Table/Fig-4]: Measurement of the distance of origin of major branches from mid vertebral line.
AA: Arch of aorta; BCT: Brachioceohalic trunk; LCCA: Left common carotid artery; LSA: Left subclavian artery; MVL: Mid vertebral line. Small black unlabelled arrows depicted in the figure show the distance of origin of above said branches from AA

STATISTICAL ANALYSIS

The mean and standard deviation for each parameter were calculated using MS Excel sheet.

RESULTS

In the present study, 50 aortic arches (45 males and 5 females) were examined. The mean diameter of the aortic arch at its origin was found to be 23.78±4.25 mm, while at its termination, it was 16.44±4.19 mm. The mean diameters of the main branches of the aortic arch were as follows: BCT:-11.22±2.29 mm, LCCA:-7.39±1.49 mm, and LSA:-8.38±2.15 mm [Table/Fig-5].

Diameter	Mean±SD (mm)
Diameter of AA at its origin	23.78±4.25
Diameter of AA at its termination	16.44±4.19
Diameter of BCT at its origin	11.22±2.29
Diameter of LCCA at its origin	7.39±1.49
Diameter of LSA at its origin	8.38±2.15

[Table/Fig-5]: The diameter of Arch of Aorta (AA) and its branches.
AA: Arch of aorta; BCT: Brachiocephalic trunk; LCCA: Left common carotid artery; LSA: Left subclavian artery

The angles made by the branches with the aortic arch were also measured. The angle made by the BCT with the AA at its origin was 89.10±18.48 degrees, the angle made by the LCCA with the AA was 73.52±14.55 degrees, and the angle made by the LSA with the AA was 73.93±16.80 degrees [Table/Fig-6].

Angles	Mean±SD (mm)	Range (min-max)
Angle made by BCT with AA at its origin	89.10±18.48	63-1200
Angle made by LCCA with AA at its origin	73.52±14.55	30-1000
Angle made by LSA with AA at its origin	73.93±16.80	35-1100

[Table/Fig-6]: The angle made by the major branches with the aortic arch.

Furthermore, the distances of origin of the branches from the midvertebral line were recorded. The distance of origin of the BCT was found to be 1.86±5.13 mm to the right of the midvertebral line, the distance of origin of the LCCA was 12.68±6.43 mm, and the distance of origin of the LSA was 26.31±6.73 mm to the left of the midvertebral line [Table/Fig-7].

Distance	Mean±SD (mm)	Range (mm)
Distance of origin of BCT from MVL	1.86±5.13	1.5-16
Distance of origin of LCCA from MVL	12.68±6.43	1.1-30
Distance of origin of LSA from MVL	26.31±6.73	12.6-40

[Table/Fig-7]: Distance of origin of major branches from mid vertebral line.
MVL: Midvertebral line

DISCUSSION

The Arch of Aorta (AA) is a vital structure in the superior mediastinum, supplying blood to the head, neck, brain, and upper extremities through its major branches-the BCT, LCCA and Left Subclavian Artery (LSA). In the present study, the diameter of the AA at its origin and termination was found to be 23.78 mm and 16.44 mm, respectively, which differs from the measurements reported by Grey H (28 mm and 20 mm, respectively) [1]. When comparing the diameters of the major vessels arising from the AA, it is worth noting that CT studies tend to report larger diameters than cadaveric studies. Even in CT studies some have considered external diameters of the branches like Aboulhoda BE et al., [7] and others studies measured their internal diameter like Kumar R and Kumar I [2]. Alsaif HA and Ramadan WS conducted a study on diameters of major branches of aortic arch on 30 human cadavers in Saudi Arabia [8]. The external diameter of LCCA (7.39 mm) in present study was comparable with the observation of Alsaif HA and Ramadan WS (9.77 mm) [8]. The diameters of BCT and LSA in the present study were not comparable , with the previous studies [7,8], as shown in [Table/Fig-8]. This may be due to the geographic differences.

Branching angles of the major vessels at their origin from the AA have been studied previously. Zamir M and Sinclair P measured these angles in 117 human specimens in 1991 [9]. The distance of origin of the major branches from the midvertebral level and the angles they make with the AA have also been examined in studies conducted on Korean and Indian cadavers [10,11]. It is clearly evident from the table of comparison that the angles made by the major

vessels of aortic arch were close to the observations from the study conducted by Chaabra K and Saini K in (2015) [Table/Fig-9] [9-11].

Parameters	Alsaif HA and Ramadan WS 2010 [8]	Aboulhoda BE et al., 2019 [7]	Present study
Diameter of BCT at its origin (mm)	17.97	15.7	11.22
Diameter of LCCA at its origin (mm)	9.77	11.42	7.39
Diameter of LSA at its origin (mm)	14.33	14.02	8.38

[Table/Fig-8]: Comparison between the diameters of branches of Arch of Aorta (AA) at their origin [7,8].
BCT: Brachiocephalic trunk; LCCA: Left common carotid artery; LSA: Left subclavian artery

Parameters	Shin Y et al., 2008 [10]	Zamir M and Sinclair P 1991 [9]	Chaabra K and Saini K 2015 [11]	Present study
Angle between AA and BCT (degrees)	65.3±25.7	54.36±13.29	94.79±17.77	89.10±18.48
Angle between AA and LCCA (degrees)	46.9±28.2	58.44±9.35	82.44±14.95	73.52±14.55
Angle between AA and LSA (degrees)	63.8±24.3	64.56±11.40	99.71±13.68	73.93±16.80

[Table/Fig-9]: Comparison between the angles made by branches of Arch of Aorta (AA) at their origin [9-11].
BCT: Brachiocephalic trunk; LCCA: Left common carotid artery; LSA: Left subclavian artery

Regarding the distance of origin of the branches from the midvertebral level, the findings of the present study were comparable to those of previous studies. The distance of origin of the BCT from the MVL line was 1.86±5.13 mm, similar to the observation of Chaabra K and Saini K (1.6±7.53 mm) [11]. The distance of origin of the LCCA from the midvertebral line was 12.68±6.43 mm, which was comparable to the observation of Shin Y et al., (12.3±8.5 mm) [10]. According to Alsaif HA and Ramadan WS the distance of origin of LSA from MVL was 25.73±7.57 mm, close to observation of the present study 26.31±6.73 mm [8]. The comparison of distance of origin of the above said branches was depicted in [Table/Fig-10] [8,10,11].

Parameters	Shin Y et al., [10]	Alsaif HA and Ramadan WS [8]	Chaabra K and Saini K [11]	Present study
Distance of BCT from MVL (mm)	0.92±7.7	9.33±4.66	1.6±7.53	1.86±5.13
Distance of LCCA from MVL(mm)	12.3±8.5	9.90±5.28	10.28±8.69	12.68±6.43
Distance of LSA from MVL (mm)	22.8±6.8	25.73±7.57	20.65±9.65	26.31±6.73

[Table/Fig-10]: Comparison between the distance of the origin of branches of AA from midvertebral line [8,10,11].
BCT: Brachiocephalic trunk; LCCA: Left common carotid artery; LSA: Left subclavian artery

In summary, the findings of the present study provide valuable information about the diameter of the AA and its branches, as well as the angles and distances of their origin. These measurements can be useful in surgical procedures and diagnostic tools. However, it is important to consider geographic and individual variations when interpreting these results.

Limitation(s)

There were a few limitations to the present study. Firstly, gender variation was not specifically analysed as the number of male cadavers (45) greatly outnumbered the female cadavers (5). This was due to the limited availability of female cadavers in the department. Secondly, age-related comparisons of the parameters were not conducted as the study included cadavers from different age groups.

CONCLUSION(S)

In the present study, various morphometric parameters of the AA and its major branches were found to differ from other studies. This could be attributed to demographic variations. The head and neck, including the brain, rely on the major vessels of the AA for their blood supply. Therefore, a detailed morphometric study of these branches is crucial for understanding haemodynamics of the head and neck and for guiding various vascular interventions performed on the aortic arch and its branches. The significance of the present study would be further enhanced with a larger sample size.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jan 27, 2023
- Manual Googling: Jul 04, 2023
- iThenticate Software: Jul 13, 2023 (12%)

ETYMOLOGY: Author Origin

EMENDATIONS: 9

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jan 23, 2023**
Date of Peer Review: **Apr 19, 2023**
Date of Acceptance: **Jul 14, 2023**
Date of Publishing: **Nov 01, 2023**