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Original Article

Anatomy Section

Anatomical Variations of Branching Pattern of the Arch of Aorta: A Cadaveric Cross-sectional Study

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ABSTRACT

Introduction: The arch of the aorta normally gives off three major branches from its convex surface. Variations in the branching pattern of the Aortic Arch (AA) are not uncommon. Knowledge of these variations is crucial during aortic instrumentation and thoracic or neck surgeries.

Aim: This study aimed to investigate the anatomical variations in the branching pattern of the AA in perinatal and adult cadavers.

Materials and Methods: A cross-sectional cadaveric study was conducted in the Department of Anatomy, at Assam Medical College and Hospital, Dibrugarh, from August 2018 to July 2021. The study included cadavers of various ages and both genders (N=46). Perinatal cadavers received from the Obstetrics and Gynecology department were also included. The thoracic cavity was opened by cutting through the costochondral junctions and reflecting the sternum. Fibrofatty tissue was removed to expose the branches of the AA, which were then examined and classified. Variations were observed, and the results were expressed in terms of frequency and percentages.

Results: A classical branching pattern (Type-A) was observed in 89.1% of cadavers. Five cadavers (10.9%), comprising four males and one female, exhibited branching patterns different from the classical pattern. Among them, Type-C variation was noted in 4 (8.7%) cadavers, and Type-D variation was found in 1 (2.2%) male cadaver.

Conclusion: Having a good understanding of the variations in the branching pattern of the arch of the aorta can be beneficial for surgeons performing complex vascular surgery.

Keywords: Brachiocephalic, Carotid, Subclavian

INTRODUCTION

The Aortic Arch (AA) is the curved continuation of the ascending aorta, beginning posterior to the 2nd right Sternocostal (SC) joint at the level of the sternal angle and ends by becoming the thoracic (descending) aorta, posterior to the 2nd left SC joint [1]. It arches superiorly, posteriorly to the left, and then inferiorly in the superior mediastinum behind the manubrium sterni. The most common branching pattern of the AA in humans includes three great vessels: the Brachiocephalic Trunk (BCT), then the Common Carotid Artery (LCCA), and finally the Left Subclavian Artery (LSA). The BCT, the first and largest branch of the arch of the aorta, arises posterior to the manubrium and ascends to reach the right side of the trachea and posterior to the right sternoclavicular joint, dividing into the right common carotid and right subclavian arteries. The LCCA, the second branch of the arch of the aorta, enters the neck. The LSA, the third branch of the arch of the aorta, ascends laterally to the left side of the trachea and passes posterior to the left sternoclavicular joint [1].

Despite many accurate preoperative protocols and adequate preparations, the complex anatomy of the region makes Vascular surgery is challenging [2]. Complications may arise due to unexpected variations in the branching pattern of AA [2]. So, prior knowledge of the variations in the branching pattern of the AA is essential before performing surgery. The study was undertaken to understand the branching pattern of the AA in the population of the Northeast region of India, a region unique for its ethnic population and distinct ecology. The findings will also contribute to the information pool on the branching pattern.

MATERIALS AND METHODS

A cross-sectional cadaveric study was conducted in the Department of Anatomy, Assam Medical College and Hospital, Dibrugarh, from August 2018 to July 2021. The study received approval from the Institutional ethics committee (Ethics No-AMC/EC/12996).

Inclusion criteria:

- Cadavers of all ages and both genders received for the dissection classes.
- All perinatal cadavers received from the Obstetrics and Gynaecology department were included in the study.

Exclusion criteria:

- Stillborn foetuses less than 32 weeks.
- Cadavers with cutting or crushing injury to the AA.
- Foetuses with gross congenital malformations.

A total of 46 cadavers (16 adults and 30 perinatal cadavers) were dissected, including 25 males and 21 females. A total of 16 adult specimens were collected from the cadavers provided for dissection, and 30 perinatal specimens were obtained from the Department of Obstetrics and Gynaecology, Assam Medical College and Hospital. All the perinatal cadavers were term stillbirths.

The cadavers were dissected using the conventional dissection method. First, a horizontal incision was made over the clavicles, and then two arched incisions were made from the xiphoid process, encircling the nipples, up to the anterior folds of the axilla. The thoracic cavities were then exposed by cutting through the centre of the clavicle and the ribs at the costal cartilages, and the sternum was reflected upwards.

The lungs were displaced on the corresponding sides to clearly expose the heart. All fat and fibrous tissues were thoroughly removed using a scalpel and forceps. The AA, from its beginning to its termination, was exposed by dissecting the structures according to the Cunningham manual of dissection [3]. The arch of the aorta was examined for its branches.

The branches of the arch were then classified according to the classification described by Kondori BJ et al. [4]. Kondori's Type-A had the classical branching pattern of the BCT, LCCA, and LSA arising independently from the AA. In Type-B, the left vertebral artery originated between the LCCA and the LSA. After branching from the AA, the left vertebral artery entered the transverse foramen of the sixth cervical vertebra and continued its normal course. In Kondori's Type-C, the AA had two branches, with the first branch being a Common Trunk (CT) for the BCT and LCCA, and the second branch being the LSA. In Type-D, there were four branches arising from the AA, with the right subclavian artery arising as the last branch of the AA and passing posterior to the esophagus.

STATISTICAL ANALYSIS

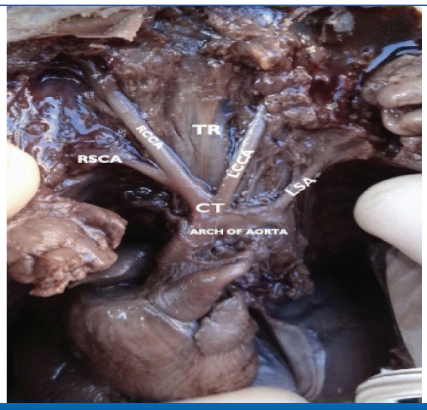
The results of the present study were reported in terms of frequency and percentage using Microsoft Excel 2021 edition.

RESULTS

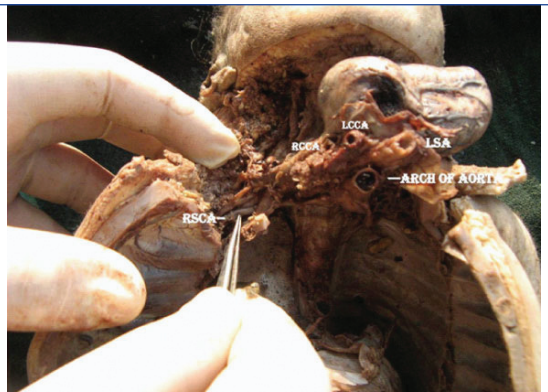
A classical branching pattern (Type-A) was observed in 41 (89.1%) of cadavers [Table/Fig-1]. Five cadavers (10.9%), comprising four males and one female, had branching patterns different from the classical pattern. Among them, Type-C variation was noted in 4 (8.7%) cadavers [Table/Fig-2], and Type-D variation was found in 1 (2.2%) male cadaver [Table/Fig-3].

Type	Male	Female	Total	Percentage
Type-A	21	20	41	89.1%
Type-B	0	0	0	0%
Type-C	3	1	4	8.7%
Type-D	1	0	1	2.2%
Total	25	21	46	100

[Table/Fig-1]: Different types of morphological variations and sex distribution of the cadavers dissected according to Kondori's classification.



[Table/Fig-2]: Two branching pattern of Arch of Aorta. (Type-C) (CT: Common trunk; RSCA: Right subclavian artery; RCCA: Right common carotid artery; LCCA: Left common carotid artery; LSA: Left subclavian artery; TR: Trachea.



[Table/Fig-3]: Four branches arising from the Aortic Arch (AA) with the right subclavian artery arising as last branch. (Type-D) (RSCA: Right subclavian artery; RCCA: Right common carotid artery; LCCA: Left common carotid artery; LSA: Left subclavian artery.

DISCUSSION

The AA develops during the 4-5 weeks of intrauterine life from three sources: the ventral part of the aortic sac, the left horn of the aortic sac, and the left fourth arch artery [5]. The brachiocephalic artery arises from the right horn of the aortic sac, while the right and left common carotid arteries arise from the 3rd arch arteries. The right subclavian artery arises from the 4th arch artery, as well as the right 7th cervical intersegmental artery. The left subclavian artery (LSA) arises from the left 7th cervical intersegmental artery. Variations in the branching pattern of the AA occur due to the abnormal persistence or disappearance of different branches [5].

In the present study, the authors observed that 10.9% (Type-C 8.7% and Type-D 2.2%) [Table/Fig-1] of cases showed variations from the classical branching pattern. The incidence of variant branching patterns in the AA ranged from 5.3% to 38.8%. Nelson ML et al., [6] reported 5.7% (n=193) and Satyapal KS et al., [7] reported 5.3% (n=320) were the lowest incidence of variation in the branching pattern. In the study (2021), we observed an incidence of 10.9% among 46 participants, which was within the range reported in other studies but more similar to Qiu Y et al., who had a slightly larger sample size of 120 cases [Table/Fig-4] [4,6-15].

Author	Year	Place of the study	Mode of study	Sample size	Percentage of Aortic Arch (AA) with variant branching pattern
Nelson ML et al., [6]	2001	Japan	Dissection	193	5.7
Satyapal KS et al., [7]	2003	South africa	Angiography	320	5.3
Natsis KI et al., [8]	2009	Greece	Angiography	633	17.0
Bhattarai C et al., [9]	2010	Nepal	Dissection	85	20.0
Alsaif HA et al., [10]	2010	Saudi arabia	Dissection	36	25.0
Patil ST et al., [11]	2012	India	Dissection	75	22.7
Budhiraja V et al.,[12]	2013	India	Dissection	52	36.5
Kondori BJ et al., [4]	2016	Iran	Angiography	226	15.1
Mustafa GA et al., [13]	2017	Jordan	Angiography	500	38.8
Qiu Y et al., [14]	2019	China	Dissection	120	11.7
Sar M et al., [15]	2021	India	Dissection	47	23.4
Present study	2021	India	Dissection	46	10.9

[Table/Fig-4]: The incidence of different branching pattern in the Aortic Arch (AA) compared to other studies [4,6-15].

In our study, Type-C variation was the second most common branching pattern of the AA, observed in 8.7% (n=4) of cases [Table/Fig-1]. The incidence of Type-C AA ranges from 1.0% to 31.2%. Mustafa GA et al. reported the highest incidence of 38.8% (n=500), while Nelson ML et al. reported the lowest incidence at 1% (n=193) [Table/Fig-5] [4,6-15].

It is important to note that the incidence of Type-C AA can vary depending on the sample size, population characteristics, and the imaging method used. Therefore, these results should be interpreted with caution, and further studies with larger sample sizes and diverse populations are needed to provide a more comprehensive understanding of the prevalence of Type-C AA.

In the study, 2.2% (n=1) had Type-D variation, which showed four independent branches of the AA, with the Right Subclavian Artery (RSA) arising as the last branch and passing posterior to the esophagus to reach the right upper limb. When the present findings were compared with different studies, it was found that the incidence of the Type-D branching pattern of the AA varied from 0.16% to 4.16%. The lowest reported incidence was 0.16% (n=633) by Natsis KI et al., while the highest incidence was reported by Qiu Y et al. at 4.16% (n=120) [Table/Fig-6] [4,6,8,14]. The fourth branch

of the AA is also known as the Aberrant Right Subclavian Artery/ Retroesophageal Right Subclavian/Arteria Lusoria [8].

Author	Year	Mode of study	Sample size	Percentage of the two-branching pattern of Aortic Arch (AA) (Type-C)
Nelson ML et al., [6]	2001	Dissection	193	1.0
Satyapal KS et al., [7]	2003	Angiogrphy	320	3.4
Bhattarai C et al., [9]	2010	Dissection	85	12.9
Natsis KI et al., [8]	2009	Angiography	633	15.0
Alsaif HA et al., [10]	2010	Dissection	36	16.7
Patil ST et al., [11]	2013	Dissection	75	14.7
Budhiraja V et al., [12]	2013	Dissection	52	19.2
Kondori BJ et al., [4]	2016	Angiography	226	12.4
Mustafa GA et al., [13]	2017	Angiography	500	31.2
Sar M et al., [15]	2021	Dissection	47	12.7
Present study	2021	Dissection	46	8.7

[Table/Fig-5]: Incidence of the two-branching pattern of Aortic Arch (AA) (Type-C) compared to other studies [4,6-15].

Author	Year	Mode of study	Sample size	Percentage of Aortic Arch (AA) with four branching pattern
Nelson ML et al., [6]	2001	Dissection	193	0.5
Natsis KI et al., [8]	2009	Angiography	633	0.16
Kondori BJ et al., [4]	2016	Angiography	226	1.8
Qiu Y et al., [14]	2019	Dissection	120	4.17
Present study	2021	Dissection	46	2.2

[Table/Fig-6]: Incidence of the four branching patterns of Aortic Arch (AA) (Type-D) compared to other studies [4,6,8,14].

Limitation(s)

As the number of available cadavers for dissection and stillbirths provided by the Department of Obstetrics and Gynaecology was limited, the study was conducted with a small sample size.

CONCLUSION(S)

The present study focused on the changes in the branching pattern of the AA, and it was observed that 10.9% of cases showed variations in the branching pattern. The standard description does not always satisfy anatomists and surgeons. A good understanding of these variations in the branching pattern of the AA would be helpful for surgeons performing complex vascular surgeries. This fundamental anatomical knowledge is important and useful, and further research with more advanced techniques is needed.

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