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Original Research Article

Variations in the Branching Pattern of Aortic Arch: An Embryological Correlation

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ABSTRACT

Background: The literature documents variations in the branching pattern of aortic arches. If not identified at the right time, these variations may lead to complications during cardiovascular surgeries or invasive procedures like angiography. Surgeons working around these variations must be well-oriented.

Methodology: the present study was conducted on 103 formalin-fixed cadavers, and their branching pattern was noted.

Results: We observed five different branching patterns in the arch of the aorta. The classical three-vessel branching pattern was noted in 70.87% of cadavers. The next common pattern was two branches arising from the arch, with the brachiocephalic trunk and left common carotid artery sharing a common origin. The left subclavian artery originated as a separate branch from the arch.

Conclusion: Around 30% of Indian individuals may show variant branching patterns of the aortic arch. This should be considered during angiography, aortic instrumentation, supra-aortic thoracic, head and neck surgery, etc. This may prevent possible complications during surgeries.

KEYWORDS: Embryology, Intervention, Intersegmental, Variant, Thyroglossal.

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INTRODUCTION

The arch of the aorta is an upward continuation of the ascending aorta, located in the superior mediastinum. It has three branches: the brachiocephalic trunk, left common carotid artery, and left subclavian artery. The brachiocephalic trunk further subdivides into the right common carotid artery and the right subclavian artery [1]. Variations like additional branches from the arch or less than three arteries from the arch are generally observed.

It's interesting to study the embryology of aortic arch branches. A series of aortic arches appear during embryological development's 4th and 5th weeks. These arches arise from the ventrally located aortic sac and terminate in the dorsal aorta. Altogether, 6 pairs of aortic arches are formed and supply the

pharyngeal arches. The disappearance of some pairs of aortic arches and the further development of others produce the characteristic morphology and asymmetry of the human arterial system. Variations in the branches of the arch of the aorta are thus likely to occur due to the altered development of some aortic arches [2,3].

The present study was conducted to study the variations in the branching pattern of aortic arches. This will generate important data for anatomists, radiologists, vascular surgeons, and thoracic surgeons. Rekha P. et al. (2012) [4] mentioned that vascular variants affect the development of other vascular structures, leading to multiple variations, thereby playing a greater role in surgical intervention in the thoracic region and angiographies [4]. Wide knowledge of the arterial pattern and its variations is important in emergency medicine and cardiothoracic surgical procedures [3]. Nayak et al. (2006) [5] quoted that identifying anomalous origins in the branches of the arch of the aorta is of great diagnostic benefit before proceeding to vascular surgeries of supra-aortic arteries as variations on these branching patterns are likely to occur as a result of the altered development of certain branchial arch arteries during the embryonic period of gestation. We reviewed the results, compared our findings with those of other authors, and analyzed the clinical implications of variations found.

MATERIALS AND METHODS

The present study was a dissection study carried out on 103 formalin-fixed adult cadavers used for teaching dissection to undergraduate students in the Anatomy department. The study was started after getting ethical approval from the Institutional Ethical Committee. Out of these 103 cadavers, 76 were males, and 27 were female. All cadavers were of Indian origin in the group of 40-80 years. During routine dissections, the thoracic cavity was opened by cutting the costochondral junctions and by manual removal of the sternum and costal cartilage. The lungs were taken out with due precautions, the superior vena cava and brachiocephalic veins were cleared, and the pericardium was opened vertically to expose the ascending aorta. Fibro-fatty tissues and nerves were removed to visualize the aortic arch and its branches. Appropriate photographs were taken, and sketches were drawn to simplify the branching patterns of the arch of the aorta. Data was tabulated and analyzed statistically.

OBSERVATIONS AND RESULTS

Five different branching patterns of the arch of the aorta were noted in the present study.

Pattern I: Classical pattern with three branches arising from the arch

Pattern II: Only two branches arising from the arch (common origin of brachiocephalic trunk & left common carotid artery. Left subclavian artery as separate branch arising from the arch)

Pattern III: Only two branches arise from the arch (Left common carotid artery arising from the brachiocephalic trunk but not as common origin from the arch). The left subclavian artery is a separate branch arising from the arch.

Pattern IV: Four branches from the arch of the aorta (left vertebral artery as a branch of the arch, arising proximal to left subclavian artery)

Pattern V: Four branches from the arch of the aorta (left vertebral artery as a branch of the arch, arising distal to left subclavian artery)

Pattern I is the usual classical pattern mentioned in the books, where three branches arise from the arch of the aorta: the brachiocephalic trunk, the left common carotid artery, and the left subclavian artery, in that order from left to right.

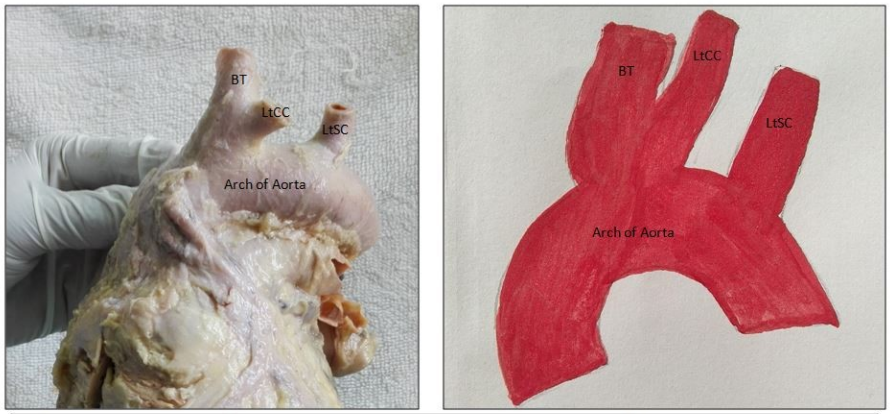
Pattern II mentions only two branches arising from the arch of the aorta: the common stem of the origin of the brachiocephalic trunk and the left common carotid artery. The left subclavian artery arises as a separate branch from the arch of the aorta (Fig. 1).

Pattern III also mentions two branches arising from the arch of the aorta. The Left common carotid artery arises as a branch from the brachiocephalic trunk but not as a common stem of origin from the arch of the aorta, as

described in pattern II. The left subclavian artery arises as a separate branch from the arch of the aorta (Fig. 2).

Pattern IV described four branches arising from the arch of the aorta- three usual branches and the left vertebral artery present proximal to the left subclavian artery. The four branches of the arch in the sequence from left to right are- the brachiocephalic trunk, left common carotid artery, left vertebral artery, and left subclavian artery (Fig. 3).

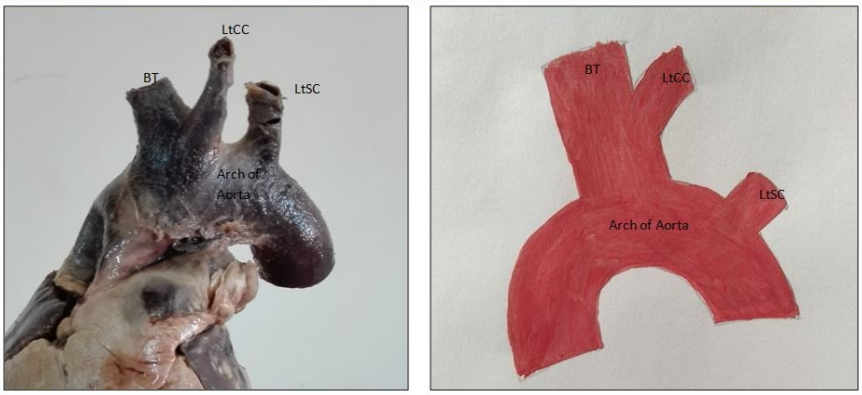
Pattern V again noted four branches arising from the arch of the aorta, but the fourth branch, the left vertebral artery, originated from the arch of the aorta distal to the left subclavian artery. From left to right, the sequence of four branches of the arch of the aorta is the brachiocephalic trunk, left common carotid artery, left subclavian artery, and left vertebral artery.



Only two branches arising from arch (common origin of brachiocephalic trunk & left common carotid artery. Left subclavian artery as separate branch arising from arch)

(BT- Brachiocephalic Trunk, LtCC- Left Common Carotid, LtSC- Left Subclavian artery)

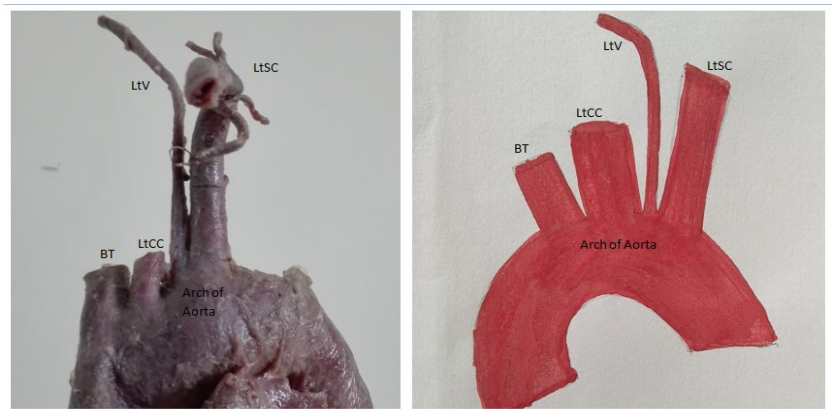
Fig. 1: Only two branches arising from the arch of the aorta



Only two branches arising from arch (Left common carotid artery arising from brachiocephalic trunk but not as common origin from arch) Left subclavian artery as separate branch arising from arch.

(BT- Brachiocephalic Trunk, LtCC- Left Common Carotid, LtSC- Left Subclavian artery)

Fig. 2: Only two branches arise from the arch of the aorta.



Pattern IV- Four branches from arch of aorta (left vertebral artery as a branch of arch, arising proximal to left subclavian artery)

(BT- Brachiocephalic Trunk, LtCC- Left Common Carotid, LtSC- Left Subclavian artery, LtV- Left Vertebral)

Fig. 3: Four branches from the arch of the aorta.

Table 1 shows the percentage of different branching patterns of the arch of the aorta found in 103 dissected cadavers. It also mentions the gender-wise distribution.

Table 1: Showing gender wise distribution of aortic arches observed in different patterns.

	Total	Percentage	Males	Females
Pattern	103	100%	76	27
I	73	70.87%	56	17
II	12	11.65%	7	5
III	8	7.77%	5	3
IV	9	8.74%	7	2
V	1	0.97%	1	0

DISCUSSION

Understanding the development of aortic arches is important before studying their branching pattern. During the embryonic period, altered development of certain aortic arch arteries leads to variations in the branching pattern of the arch of the aorta. Six pairs of aortic arches are formed, connecting the side of the aortic sac with the corresponding dorsal aortae. Further, there is extensive transformation and reduction in aortic arches to form a final and asymmetric arterial system. The part of the arch of the aorta between the origins of the brachiocephalic trunk and the left common carotid artery is generally formed due to the incorporation of the left limb of the aortic sac. The proximal part of the third aortic arch normally gets extended and absorbed into the left horn of the aortic sac. If it gets absorbed into the right horn of the aortic sac, it results in a variable branching pattern [6,7].

The present study observed a classical branching pattern of three branches (Pattern I) in 70.87% of cadavers. Rekha P et al. [4] noted a classical pattern in 92.72% of hearts. The other authors noted various percentages of classical branching patterns in the Indian population- Rekha P et al. (2013) [4] in 92.72% of hearts, Budhiraja V. et al(2013) [8] in 63.5% of hearts, Nayak et al (2006) [5] in 91.4% of hearts.

Pattern II, with only two arteries arising from the arch, was noted in 11.65% of hearts. Rekha P et al. (2013) observed such a pattern in only 2.72% of cadaveric hearts, and Budhiraja et al. found it in 19.2% of cadaveric hearts. This was the most common variant branching pattern noted in our study.

Very little literature was found that mentions the type III pattern. It shows only two branches arising from the arch- the common trunk and the left subclavian artery. (The left common carotid artery arising from the brachiocephalic trunk but not a common origin from the arch). Paraskevas et al (2008) [9] noted origin of left common carotid artery from initial part of brachiocephalic artery in 81-year Caucasian cadaver. The frequency of this occurrence was reported to be 0.2%.

As pattern IV noted in the present study, the fourth branch, i.e., the left vertebral artery, originated from the arch of the aorta. Its percentage was noted as 8.74% in the present study. The vertebral artery is classically described as the first branch of the subclavian artery. But, multiple variations in the origin of the vertebral artery have been reported in the literature; the most frequent variant (2.4-5.8%) is the left vertebral artery arising directly from the aortic arch between the left common carotid artery and left subclavian artery [1,10]. The same pattern was observed in 6.7% of the African population by Kerry Keet [11]. The first part of the vertebral artery usually originates from the seventh inter-segmental artery [12]. Left vertebral artery originating from the aortic arch results when this vessel develops from the sixth cervical intersegmental artery together with the persistence of a portion of the dorsal aorta [11,12,13]. Bhatia K (2005) [3] has mentioned that the increased incidence of aortic origin of the left vertebral artery may be due to genetic and environmental causes. Environmental causes may include changes in maternal nutrition, exercise patterns, psychological stressors, health care, and many other environmental factors that have altered over the last century [3].

The important observation of this study is the absence of thyroidea ima artery in all cadavers. When the thyroidea ima artery is present, it may arise from the brachiocephalic artery, aortic arch, right common carotid artery, subclavian artery, or internal thoracic

artery. The absence of the thyroidea ima artery may be a consequence of a delayed migration of the thyroid gland along the path of the thyroglossal duct in such a way that it lags behind the descending arch of the aorta, leading to attenuation and regression of any arterial contribution to the gland from the arch of the aorta [3].

Such arterial anomalies are critical during neck surgeries and even more important in percutaneous dilatational tracheostomy, which has gained wide acceptance due to its relative speed, simplicity, and ability to be performed on the bedside, as this variant anatomy may block the site for tracheostomy [14]. Knowledge of variations of great vessels is of vital interest to surgeons because a minor accidental injury of the vessels causes sudden massive hemorrhage [8].

CONCLUSION

Knowledge of variations of the aortic arch branches is important in emergency medicine and cardiothoracic surgery. Variant branching patterns of the aortic arch should be considered during angiographies, aortic instrumentation, supra-aortic thoracic, or head and neck surgery. The surgeon must be aware of any possible variations of the major arteries and should be able to identify them. Correct identification of these vessels is crucial for appropriate invasive procedures to achieve desired objectives and avoid complications during vascular surgery.

Author Contributions

Vaibhav Anjankar- acquisition of data, drafting the manuscript,
Kanchankumar Wankhede- conception and design, final version editing
Shital Hajare- analysis and interpretation of data

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Conflicts of Interests: None

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