Prevalence and Classification of Aortic Arch Branching Patterns: A Cadaveric Study on 120 Adult Human Specimens

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Abstract Introduction: *Background: The aortic arch exhibits considerable anatomical variability in its branching pattern, with important implications for cardiothoracic surgery, vascular interventions, and diagnostic imaging. Population-specific data on the prevalence of branching variants remain limited, particularly from cadaveric studies.* ***Aim:*** *To determine the prevalence and distribution of aortic arch branching patterns in adult human cadavers and to evaluate their association with sex and age.* ***Materials and Methods:*** *A descriptive cross-sectional study was conducted on 120 formalin-fixed adult cadavers (72 male, 48 female; mean age 56.42 ± 14.28 years). The aortic arch was dissected using a standardized protocol and branching patterns were classified according to the modified Natsis classification. Chi-square tests were used to compare distributions between sexes and age groups.* ***Results:*** *The classical three-branched pattern (Type I) was observed in 76.67% of cadavers. Variant patterns were present in 23.33%, with the bovine arch (Type II) being most common (12.50%), followed by direct origin of the left vertebral artery from the arch (Type III, 5.00%), two-branch pattern (Type IV, 3.33%), aberrant right subclavian artery (Type V, 1.67%), and other rare variants (Type VI, 0.83%). No statistically significant differences were found in branching pattern distribution between sexes (x^2 = 0.132, p = 0.716) or across age groups (x^2 = 0.547, p = 0.908).* ***Conclusion:*** *Variant aortic arch branching patterns are present in nearly one-quarter of the study population, underscoring the need for routine preoperative imaging assessment. The branching pattern is independent of sex and age, consistent with its embryological determination.*

Keywords: *Aortic arch; branching pattern; anatomical variation; bovine arch; cadaveric study; arteria lusoria; left vertebral artery*

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INTRODUCTION

The aortic arch is one of the most critical segments of the arterial system, serving as the origin for the great vessels supplying the head, neck, and upper extremities. The classical branching pattern consists of three separate branches arising from the convexity of the arch: the brachiocephalic trunk, the left common carotid artery, and the left subclavian artery. This standard configuration is reported in 64.9% to 94.3% of individuals depending on the population studied and the methodology employed [1–3].

However, a significant minority of individuals exhibit variant branching patterns arising from variations in the embryological development of the pharyngeal arch arterial system. These variations include the bovine arch (common origin of the brachiocephalic trunk and left common carotid artery), direct origin of the left vertebral artery from the arch, aberrant right subclavian artery (arteria lusoria), and various rare configurations [4–6]. The clinical significance of these variations extends across cardiothoracic surgery, vascular surgery, interventional radiology, and diagnostic imaging [7,8].

Population-based differences in the prevalence of aortic arch branching variants have been well documented, with African populations showing higher rates of variant patterns compared to European and East Asian populations [9,10]. Despite this, cadaveric data from many populations remain limited. The present study was undertaken to determine the prevalence and distribution of aortic arch branching patterns in a cadaveric population, and to evaluate their association with sex and age.

MATERIALS AND METHODS

Study Design and Population

This descriptive cross-sectional observational study was conducted in the Department of Anatomy at a tertiary care teaching center over a two-year period (January 2023 to December 2024). A total of 120 formalin-fixed adult human cadavers (72 male and 48 female) were included. The study was approved by the Institutional Ethics Committee (IEC/2023/XX) and all procedures were conducted in accordance with the Declaration of Helsinki.

Inclusion criteria comprised adult cadavers aged 18 years and above with intact thoracic cavities and adequate formalin fixation. Cadavers with previous thoracic surgery, gross aortic pathology, significant post-mortem deterioration, traumatic thoracic injury, previous dissection of the aortic arch, or incomplete demographic information were excluded.

Dissection Technique

A standardized dissection protocol was followed. After midline sternotomy, the mediastinal structures were carefully dissected to expose the aortic arch and all its branches. Each branch was identified, traced along its course, and named. The number of branches, their order of origin, and the type of branching pattern were recorded. Photographic documentation was obtained for each specimen.

Classification

Branching patterns were classified according to the modified Natsis classification: Type I (Standard) – three separate branches; Type II (Bovine Arch) – left common carotid artery arising from or sharing a common origin with the brachiocephalic trunk; Type III (Four-Branch Pattern) – left vertebral artery arising directly from the arch; Type IV (Two-Branch Pattern) – common trunk for brachiocephalic artery and left common carotid; Type V (Aberrant Right Subclavian) – right subclavian arising as last branch; Type VI (Other Rare Variants) [1].

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0. Categorical variables were expressed as frequencies and percentages. The chi-square test was used to compare branching pattern distribution between sexes and across age groups. A p-value < 0.05 was considered statistically significant.

RESULTS

The 120 cadavers comprised 72 males (60.0%) and 48 females (40.0%). The age at death ranged from 25 to 85 years, with a mean age of 56.42 ± 14.28 years. There was no significant difference in mean age between sexes (males: 55.83 ± 14.52 years; females: 57.31 ± 13.95 years; p = 0.571).

Prevalence of Branching Patterns

The distribution of aortic arch branching patterns is presented in Table 1. The classical three-branched pattern (Type I) was the most prevalent configuration, observed in 92 cadavers (76.67%). Variant branching patterns were collectively observed in 28 cadavers (23.33%).

Table 1: Distribution of Aortic Arch Branching Patterns (n = 120)

Type	Description	n	%	Male	Female
I	Standard (3 branches)	92	76.67	56	36
II	Bovine arch	15	12.50	8	7
III	LVA from arch (4 branches)	6	5.00	4	2
IV	Two-branch pattern	4	3.33	2	2
V	Aberrant RSA	2	1.67	1	1
VI	Other rare variants	1	0.83	1	0
	Total	**120**	**100**	**72**	**48**

LVA = left vertebral artery; RSA = right subclavian artery

Sex-wise Distribution

Variant branching patterns were observed in 22.22% of males and 25.00% of females. There was no statistically significant difference in the distribution of standard versus variant patterns between sexes ($\chi^2 = 0.132$, p = 0.716) (Table 2).

Table 2: Sex-wise Distribution of Branching Patterns

Pattern	Male n(%)	Female n(%)	χ^2	p-value
Standard	56 (77.78)	36 (75.00)		
Variant	16 (22.22)	12 (25.00)	0.132	0.716
Total	**72 (100)**	**48 (100)**		

Age-wise Distribution

There was no statistically significant difference in the distribution of branching patterns across age groups ($\chi^2 = 0.547$, p = 0.908) (Table 3).

Table 3: Age-wise Distribution of Branching Patterns

Age Group (yrs)	Standard n(%)	Variant n(%)	χ^2	p-value
25–40	17 (77.27)	5 (22.73)		
41–55	29 (76.32)	9 (23.68)		
56–70	31 (79.49)	8 (20.51)		
>70	15 (71.43)	6 (28.57)		
Total	**92 (76.67)**	**28 (23.33)**	**0.547**	**0.908**

DISCUSSION

The present study found the classical three-branched pattern in 76.67% of cadavers, consistent with the globally reported range of 65–94% [1–3]. This prevalence is comparable to 78.9% reported in a Bangladeshi population and 82.3% reported in an Indian population, but notably lower than 89.2% reported in a Chinese population, reflecting population-specific differences [6,11,12].

The bovine arch was the most common variant at 12.50%, consistent with the 10–15% range reported in most Asian and European studies, and lower than the 20–27% reported in African and multiethnic American populations [9,10,13]. The term “bovine arch” is a misnomer as this pattern does not occur in cattle, but remains widely used. This variant has clinical significance for thoracic endovascular aortic repair (TEVAR), where it may affect proximal landing zone availability [14].

The direct origin of the left vertebral artery from the aortic arch was observed in 5.00%, within the 2.4–8% range reported in the literature [15,16]. This variant is clinically relevant as the vertebral artery arising directly from the arch typically has a larger caliber and may serve as a dominant source of posterior circulation supply, with implications for endovascular treatment of posterior circulation disorders.

The aberrant right subclavian artery was identified in 1.67%, within the commonly reported range of 0.5–2.0% [17,18]. In both cases, the aberrant vessel coursed posterior to the esophagus, consistent with the most common trajectory described in the literature. This variant is important to recognize preoperatively in patients undergoing esophageal surgery, mediastinal surgery, or right-sided central venous access.

The absence of significant sex-based ($\chi^2 = 0.132$, $p = 0.716$) or age-based ($\chi^2 = 0.547$, $p = 0.908$) differences in branching pattern distribution is consistent with the majority of previous studies, and supports the concept that the branching pattern is determined during embryological development and remains stable throughout postnatal life regardless of sex or age [19,20].

The study has certain limitations. Formalin-fixed cadavers may not fully represent the general living population. The sample size, while adequate for prevalence estimation, may be insufficient for detecting differences in rare variants. The cross-sectional design precludes assessment of temporal changes.

CONCLUSION

Variant aortic arch branching patterns are present in 23.33% of the study

population, with the bovine arch being the most common variant (12.50%). The branching pattern is independent of sex and age, consistent with its embryological determination. The significant proportion of anatomical variants underscores the importance of routine preoperative imaging assessment of aortic arch anatomy for surgical and interventional planning. These population-specific prevalence data contribute to the growing body of knowledge essential for safe clinical practice.

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