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Research Article

# Morphometric Parameters of the Aortic Arch and Its Branches: Sex-Based and Age-Related Variations in a Cadaveric Study

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**Abstract:** ***Background:*** Accurate morphometric data of the aortic arch and its branches are essential for planning surgical and endovascular procedures. Population-specific reference values accounting for sex and age are particularly important for optimal device sizing and procedural planning. ***Aim:*** To determine the morphometric parameters of the aortic arch and its branches and evaluate their relationship with sex, age, and branching pattern type. ***Materials and Methods:*** A cross-sectional study was conducted on 120 formalin-fixed adult cadavers (72 male, 48 female; mean age 56.42 ± 14.28 years). Morphometric measurements of the aortic arch including diameters, arch length, branch diameters, and inter-branch distances were obtained using digital Vernier calipers. Independent t-tests, one-way ANOVA, and Pearson's correlation were used for analysis. ***Results:*** All morphometric parameters were significantly larger in males than females ($p < 0.001$). The mean aortic arch diameter at origin was 28.45 ± 3.12 mm in males versus 25.78 ± 2.89 mm in females. Significant positive correlations were found between age and aortic arch diameter ($r = +0.412$, $p < 0.001$), arch length ($r = +0.345$, $p < 0.001$), and branch diameters ($p < 0.05$). The brachiocephalic trunk diameter was significantly larger in the bovine arch group (14.89 ± 2.12 mm) compared to the standard pattern group (13.45 ± 1.89 mm; $p = 0.023$). Inter-branch distances did not correlate significantly with age. Conclusion: Significant sex-based and age-related differences exist in aortic arch morphometry. These population-specific reference values are valuable for sex- and age-adjusted procedural planning in surgical and endovascular interventions.

**Keywords**: Aortic arch; morphometry; sexual dimorphism; age-related changes; cadaveric study; endovascular surgery; vascular dimensions demands.

## Introduction

Precise knowledge of the dimensional characteristics of the aortic arch and its branches is fundamental to the planning and execution of a wide range of cardiothoracic and endovascular surgical procedures. The aortic arch dimensions directly influence cannulation strategies, cerebral protection techniques, stent-graft sizing during thoracic endovascular aortic repair (TEVAR), and the approach to reimplantation of great vessels during open aortic surgery [1–3].

The morphometric parameters of the aortic arch are influenced by several demographic factors, particularly sex and age. The well-established sexual dimorphism in cardiovascular anatomy results in consistently larger aortic dimensions in males compared to females [4,5]. Age-related vascular remodeling, characterized by progressive degeneration of elastic fibers in the aortic media, leads to gradual dilatation of the aorta with advancing age [6,7]. Additionally, the branching pattern configuration may itself be associated with altered vessel dimensions, as suggested by recent hemodynamic studies [8].

Despite the clinical importance of these measurements, population-specific morphometric reference data remain scarce, particularly from cadaveric studies that allow direct measurement without the limitations inherent in imaging-based assessment. The present study was undertaken to establish morphometric reference values for the aortic arch and its branches, and to evaluate the influence of sex, age, and branching pattern type on these parameters.

## Materials And Methods

This descriptive cross-sectional study was conducted on 120 formalin-fixed adult human cadavers (72 male, 48 female) in the Department of Anatomy at a tertiary care teaching center over a two-year period (January 2023 to December 2024). The study was approved by the Institutional Ethics Committee. Cadavers with previous thoracic surgery, gross aortic pathology, significant post-mortem deterioration, or incomplete demographic information were excluded.

Following standardized midline sternotomy and careful dissection of the aortic arch, morphometric measurements were obtained using digital Vernier calipers (accuracy 0.01 mm). Parameters measured included: diameter of the aortic arch at its origin and at the isthmus, length of the arch along its superior convexity, arch height, diameter of each branch at its origin, and distance between origins of consecutive branches. All measurements were taken three times and the mean value was recorded [9,10].

Statistical analysis was performed using SPSS version 26.0. Continuous variables were expressed as mean ± SD. The independent t-test was used to compare measurements between sexes. One-way ANOVA with Tukey's HSD post-hoc test compared measurements across branching pattern types. Pearson's correlation coefficient assessed the relationship between age and morphometric variables. A p-value < 0.05 was considered statistically significant.

## RESULTS

The study population comprised 72 males (60.0%) and 48 females (40.0%), with a mean age of 56.42 ± 14.28 years (range: 25–85 years). The mean age was comparable between sexes (p = 0.571).

**Aortic Arch Dimensions by Sex**

All morphometric parameters of the aortic arch were significantly larger in males compared to females (Table 1). The mean aortic arch diameter at its origin was 28.45 ± 3.12 mm in males versus 25.78 ± 2.89 mm in females (p < 0.001).

**Table 1: Morphometric Parameters of the Aortic Arch by Sex (mean ± SD, in mm)**

| Parameter | Male (n=72) | Female (n=48) | t-value | p-value |
|---|---|---|---|---|
| Diameter at origin | 28.45±3.12 | 25.78±2.89 | 4.82 | 0.001* |
| Diameter at isthmus | 23.67±2.85 | 21.34±2.54 | 4.59 | 0.001* |
| Length of arch | 72.34±8.56 | 65.21±7.43 | 4.78 | 0.001* |
| Arch height | 25.89±3.45 | 23.12±3.01 | 4.56 | 0.001* |

**Statistically significant (p < 0.05)*

**Branch Diameters by Sex**

**Table 2: Diameter of Aortic Arch Branches at Their Origin by Sex (mean ± SD, in mm)**

| Branch | Male | Female | t-value | p-value |
|---|---|---|---|---|
| Brachiocephalic trunk | 14.23±1.89 | 12.56±1.65 | 5.01 | 0.001* |
| Left common carotid | 7.82±1.12 | 6.95±0.98 | 4.42 | 0.001* |
| Left subclavian | 9.15±1.34 | 8.12±1.18 | 4.36 | 0.001* |
| Left vertebral (n=6) | 4.85±0.62 | 4.21±0.45 | 1.52 | 0.189 |

**Statistically significant (p < 0.05)*

**Inter-branch Distances**

**Table 3: Inter-branch Distances by Sex (mean ± SD, in mm)**

| Distance | Male | Female | t-value | p-value |
|---|---|---|---|---|
| BCT to LCCA | 6.85±2.34 | 5.92±2.01 | 2.26 | 0.026* |
| LCCA to LSA | 8.34±2.67 | 7.21±2.23 | 2.42 | 0.017* |
| BCT origin to LSA origin | 15.19±3.89 | 13.13±3.12 | 3.06 | 0.003* |

**Statistically significant (p < 0.05). BCT = brachiocephalic trunk; LCCA = left common carotid artery; LSA = left subclavian artery*

**Morphometric Parameters Across Branching Pattern Types**

The brachiocephalic trunk diameter was significantly larger in the bovine arch group compared to the standard pattern group (p = 0.023). Other arch parameters did not differ significantly across branching types (Table 4).

**Table 4: Aortic Arch Parameters Across Branching Types (mean ± SD, in mm)**

| Parameter | Type I (n=92) | Type II (n=15) | Type III (n=6) | F | p |
|---|---|---|---|---|---|
| Arch dia (origin) | 27.12±3.25 | 28.05±2.98 | 27.89±3.45 | 0.672 | 0.512 |
| Arch dia (isthmus) | 22.45±2.78 | 23.12±2.45 | 22.98±3.01 | 0.534 | 0.588 |
| Arch length | 68.89±8.23 | 70.23±7.89 | 69.45±9.12 | 0.198 | 0.821 |
| BCT diameter | 13.45±1.89 | 14.89±2.12 | 13.23±1.78 | 3.89 | 0.023* |

**Statistically significant (p < 0.05)*

### Correlation Between Age and Morphometric Parameters

Significant positive correlations were observed between age and the diameters of the aortic arch and its branches. The strongest correlation was with the aortic arch diameter at origin (r = +0.412, p < 0.001). Inter-branch distances did not show significant correlations with age (Table 5).

**Table 5: Pearson's Correlation Between Age and Morphometric Parameters**

| Parameter | r (Pearson) | p-value |
|---|---|---|
| Aortic arch diameter (origin) | +0.412 | 0.001* |
| Aortic arch diameter (isthmus) | +0.378 | 0.001* |
| Arch length | +0.345 | 0.001* |
| BCT diameter | +0.289 | 0.001* |
| LCCA diameter | +0.198 | 0.030* |
| LSA diameter | +0.212 | 0.020* |
| BCT to LCCA distance | +0.156 | 0.089 |
| LCCA to LSA distance | +0.142 | 0.122 |

**Statistically significant ($p < 0.05$)*

## Discussion

The present study provides comprehensive morphometric data on the aortic arch and its branches, demonstrating significant sex-based and age-related variations that are of direct clinical relevance.

The significantly larger aortic arch dimensions in males compared to females observed in this study are consistent with the well-established sexual dimorphism in cardiovascular anatomy [4,5,11]. The mean aortic arch diameter at origin (28.45 mm in males vs. 25.78 mm in females) and branch diameters are comparable to those reported in recent cadaveric and imaging studies from similar populations [12,13]. These sex-based differences have critical implications for the sizing and selection of endovascular devices, including stent-grafts for TEVAR and catheters for arch vessel interventions. The use of population-average values without sex-specific adjustment may result in suboptimal device selection, underscoring the need for sex-stratified reference data.

The significant positive correlations between age and aortic arch dimensions are consistent with the well-documented age-related vascular remodeling attributable to progressive elastic fiber degeneration [6,7,14]. The finding that aortic arch diameter increases with age (r = +0.412, p < 0.001) is comparable to previous CT angiographic studies reporting an increase of approximately 1.5 mm per decade [14]. Notably, the inter-branch distances did not correlate significantly with age, suggesting that while overall arch dimensions expand with age, the relative spacing between branch origins remains stable. This has practical implications: the available landing zones between branches for endovascular device deployment may not change significantly with age, even as overall arch dimensions increase.

The finding that the brachiocephalic trunk diameter was significantly larger in the bovine arch group (14.89 mm) compared to the standard pattern group (13.45 mm) is noteworthy. This may reflect altered hemodynamic conditions created by the common origin configuration, leading to vessel remodeling. Previous studies have reported an association between the bovine arch and thoracic aortic aneurysm, suggesting that altered flow dynamics may predispose to aortic wall degeneration [8,15]. Our morphometric data support this hypothesis and may be relevant for device sizing in patients with bovine arch anatomy undergoing endovascular procedures.

The study has certain limitations including the use of formalin-fixed cadavers (which may result in tissue shrinkage), potential selection bias inherent in cadaveric populations, and the cross-sectional design. Nonetheless, cadaveric dissection provides direct visualization and measurement unhindered by the limitations of imaging-based assessment.

## Conclusion

This study establishes population-specific morphometric reference values for the aortic arch and its branches that demonstrate significant sex-based and age-related variations. Males have consistently larger aortic arch dimensions than females across all parameters. Age is positively correlated with vessel diameters but not inter-branch distances, reflecting age-related vascular dilatation without alteration of relative branch spacing. The bovine arch is associated with a significantly larger brachiocephalic trunk diameter, suggesting altered hemodynamic remodeling. These data provide a valuable foundation for sex- and age-adjusted procedural planning in surgical and endovascular interventions involving the aortic arch.

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