

Anatomical Branching Patterns of the Aortic Arch in Ethiopia: An Imaging-based Study

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Abstract

Background: The aortic arch (AA) is a key anatomical vascular structure through which blood is distributed to the body's organs. Knowledge of its branching patterns is important for surgical procedures. This study aimed to describe anatomical variations in the branching patterns of human AAs in patients who underwent chest contrast-enhanced computed tomography. **Methods:** A retrospective study involving 630 chest contrast-enhanced computed tomography scans from July 2018 to July 2019 was carried out at Ayder Comprehensive Specialized Hospital, Mekelle, Ethiopia. These images were reviewed for AA branching patterns and classified accordingly. Data were analyzed using SPSS version 21. **Results:** Of the 630 patients (364 males and 266 females), AA branching pattern variations were found in 35.2%: type II, 26%; type III, 6.5%; type V, 2.7%; the rest, 64.8%, had a normal (type I) AA branching pattern.

The left vertebral artery and the aberrant right subclavian artery were also observed to originate directly from the AA. **Conclusions:** AA branching pattern variation types II, III, and V were found in our study. These findings could be vital during aortic instrumentation and surgical procedures of the head and neck in Ethiopia and globally.

Keywords: Anatomical variants, Aortic arch, Branching patterns, Surgical procedures

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Introduction

The aortic arch (AA) is the curved continuation of the ascending aorta supplying the head, neck, and the upper thoracic region (1). Its normal branching pattern, which occurs in 64.9 to 94.7% of the population, is (from proximal to distal) from the brachiocephalic trunk (BT), to the left common carotid artery (LCC), and finally, to the left subclavian artery (LS) (2-4). Occasionally, this vascular pattern may vary (5). This can be explained by the persistence of AA segments that normally regress, the disappearance of segments that would otherwise remain, or both (5,6).

Variations of the AA may cause dyspnea, dysphasia, intermittent claudication, changes in cerebral hemodynamics, misinterpretation of radiological examinations, and complications during neck and thorax surgery (7). This is important both for diagnostic value and before surgery of supra-aortic arteries (8).

AA variant branching patterns are most commonly studied using cadaver dissection and radiology. Comparisons of studies carried out in China, Greece, Turkey, and Kenya revealed an almost similar number of variation types despite using the different study methods (9-13). Prevalence of these variations also

differs among populations. A South Australian cadaveric study reported a prevalence of 7.41% (14), whereas the prevalence was 11.67% in China (9) and 20% in Nepal (15). The prevalence is reportedly higher in African populations (up to 49.7%) (6). Despite the varying prevalence of AA branching pattern variations, this has not been studied in Ethiopia.

The present study intended to investigate the variations in branching patterns of the AA in Ethiopian populations that may be important for surgical planning and endovascular procedures.

Materials and methods

Study setting and design

This study was conducted in Ayder Comprehensive and Specialized Hospital (ACSH), Mekelle, Ethiopia. ACSH is Ethiopia's second-largest referral hospital and serves a wide catchment population of more than 8 million people.

A retrospective study was carried out to determine the variations in AA branching patterns among patients who underwent contrast-enhanced computed tomography (CECT) of the chest for various indications. The data collection period was between July and August 2019.

Inclusion criteria

All patients who had undergone CECT of the chest from July 1, 2018, to July 30, 2019, and with complete chest CT scans (including the supra-aortic vessels superior to the diaphragm) were included in the study population.

Exclusion criteria

Patients who underwent CECT of the chest with incomplete information, had marked motion artifact in the region of interest (difficult to visualize AA vessels), no AA images available for review, and had a prior arch reconstructive surgery were excluded from the study.

Sampling procedure

Convenience sampling, aimed at including the maximum number of patients within the limited data collection period available, was utilized. Data were obtained from the hospital's Picture Archiving and Communication System. All patients who had

undergone chest CECT and fit the study criteria were included.

AA branching pattern variations and classification

The classification of AA variation in this study was adapted from the Natsis classification (10), which is also radiology based: type I: BT, LCC, and LS; type II: BT with LCC and LS; type III: BT, LCC, left vertebral artery (LV), and LS; type IV: right subclavian artery (RS) and carotids in common-LS; type V: carotids in common-LS, RS; type VI: carotids and subclavians in common; type VII: RS, right common carotid artery (RCC), LCC, and LS; type VIII: BT, thyroidea ima, LCC, and LS.

Study variables

Study variables included patients' demographic characteristics (age and sex), types of AA branching variations, number, and distribution of the branches (origin of additional arteries from the AA).

Data collection process and tools

Patients' medical record numbers were collected, and the corresponding patients' files and scans were retrieved. Data from patients fitting the inclusion criteria were collected using a checklist that had been developed based on the variables defined in the study, which were obtained from various literature.

Senior radiologists evaluated CECT images of the chest and assessed aortic branching variants. The structure of the AA and its branches were determined on the axial sections. Coronal, sagittal, and volume-rendered three-dimensional reconstruction images were also used where uncertainty existed on axial images.

The investigators closely supervised the data collection process for completeness and clarity. Personal identification details were omitted and data were secured in a password-coded file to ensure confidentiality.

Data processing and analysis

Data were analyzed using SPSS version 21 (IBM Corp., Armonk, NY, USA) and presented in tables and macrographs. Pearson chi-square test was used to check

whether there were any significant differences in the incidence of variations and sex. A p value<0.05 was considered statistically significant.

Ethical clearance

Ethical clearance was obtained from the Health Research and Ethics Review Committee at the College of Health Sciences, Mekelle University (reference number 1392/2019).

Table 1. Patients’ age and sex characteristics according to aortic arch branching patterns (n =630)

Variable	Variation Type					P-Value
	Type I	Type II	Type III	Type V	Total	
Sex						
Male	238 (65.4)	91 (25)	23 (6.3)	12 (3.3)	364 (57.8)	0.66
Female	170 (63.9)	73 (27.4)	18 (6.8)	5 (1.9)	266 (42.2)	
Total	408 (64.8)	164 (26.0)	41 (6.5)	17 (2.7)	630 (100)	
Age category						
<50 years	220 (65.0)	80 (23.8)	24 (7.1)	12 (3.6)	336 (53.3)	0.32
50–65 years	106 (62.0)	54 (31.6)	7 (4.1)	4 (2.3)	171 (27.1)	
66–79 years	57 (64.8)	21 (23.9)	9 (10.2)	1 (1.1)	88 (14.0)	
≥80 years	25 (71.4)	9 (25.7)	1 (2.9)	0 (0.0)	35 (5.6)	
Total	408 (64.8)	164 (26.0)	41 (6.5)	17 (2.7)	630 (100.)	

Values are presented as n (%).

Results

Type I (normal) AA branching pattern was seen in 64.8% of the patients. A total of 222 (35.2%) patients had anatomical variations in AA branching. Of these, the bovine arch was the most common variation observed, accounting for 164 (26.0%) of the patients, followed by types III (6.5%) and IV (2.7%).

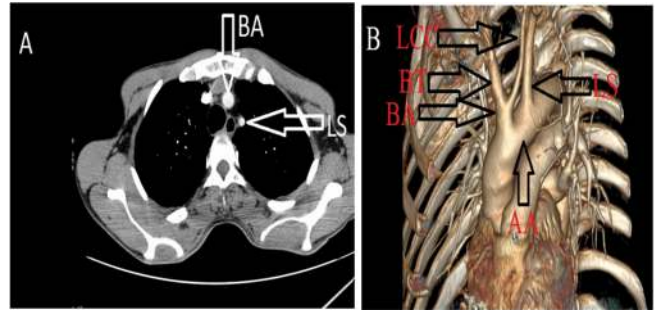


Figure 1. Type II variation of the aortic arch.

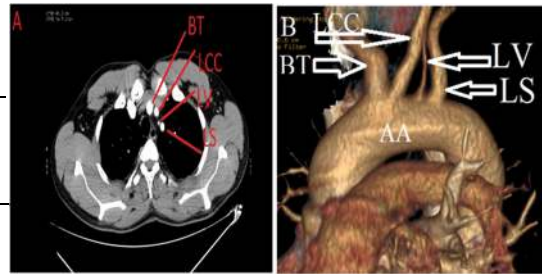


Figure 2. Type III variation of the aortic arch.

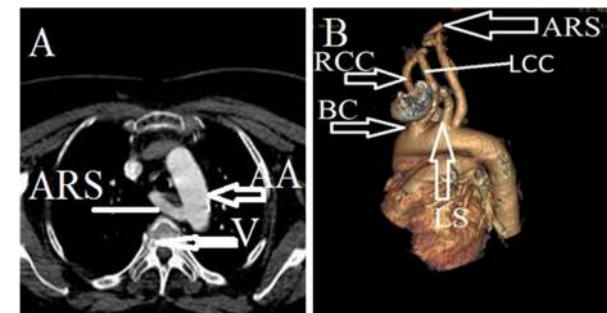


Figure 3. Type V variation of the aortic arch

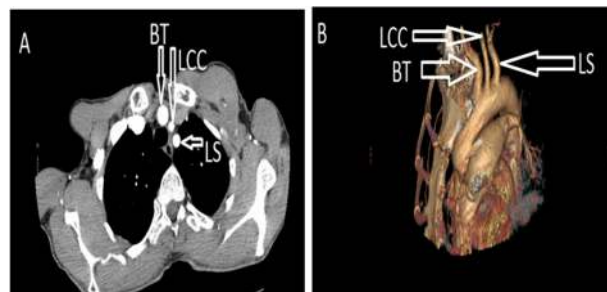


Figure 4. Type I aortic arch (AA) branching pattern.

Of the patients with AA branching pattern variations, 126 (56.8%) were males, whereas 96 (43.2%) were females. The majority of variations observed were found more frequently in younger (<50 years) patients, followed by those between 50 and 65 years, those between 66 and 79 years, and those ≥80 years. The mean

age of the participants was 46.96 ± 20.03 years (Table 1).

The predominantly identified variation was the bovine arch (type II) in which the LCC has a common origin with the BT and then the LS. In type III, the left vertebral artery originated directly from the AA between the LCC and the LS, whereas in type V, the aberrant right subclavian artery originated directly from the arch of aorta distal to the LS. Normal (type I) branching pattern was also observed (Figures 1-4).

Discussion

Most of the patients in our study were male. Sex was, however, not found to be significantly associated with the presence of AA variation, which was consistent with the findings of Karacan et al. (11) and Amakabane and Mwangi (12). There was also no significant association found in this study between AA variations and age at the time of imaging.

Natsis type I was the most common AA branching pattern in this study. Its prevalence was only slightly lower than the commonly reported prevalence of 64.9–94.3% (3,4). Similar findings have been found in South African and Turkish studies (11,16). AA variations had a prevalence of 35.2% in our study, which was similar to the findings of Berko et al. (17). It is, however, higher than incidences reported in other studies, such as in Turkey (18). AA variations have generally been reported to be higher in African populations than in Caucasians (13).

The most common AA variant was the bovine arch (type II), making this study comparable to that of Lale et al. (18), who used computed tomographic angiography in their work. On the contrary, Bhatia et al. reported type III variant as the most common in a South Australian cadaveric study (14). Bovine AA is generally considered a normal variation in AA branching pattern; however, this variation has also been reported to be associated with a higher incidence of congenital cardiovascular diseases. It also carries a 1% to 3% risk of retrograde aortic dissection during or after thoracic endovascular aortic repair (19).

We found that the second most frequent variant was type III, which was within the reported prevalence of 2.4–8%

in literature (3). Natsis et al. (10) also found type III AA variation in their study but with a much lower prevalence than that in our study. The prevalence was, however, higher in a study by Demertzis et al. (20). This variation has been postulated to arise due to several mechanisms. These include temporary variation in the release of growth factors such as vascular endothelial growth factor A164/165 and placenta growth factor. These may increase or decrease, causing the LV to arise from the AA rather than the LS. Embryologically, it could be that the vertebral artery develops from the persistent sixth cervical intersegmental artery and the segment of the dorsal aorta that fails to disappear. This may reduce blood flow through this atypical origin of the LV from the AA (21). Tardieu et al. found that vertebral arteries that arose from the AA were much more likely to have a more medial course (especially their pre-foraminal segment) over the cervical vertebral bodies. They would also likely enter the transverse foramen that is more cranially located than the normal C6 entrance of the vertebral artery. This makes them more prone to iatrogenic injury while approaching the anterior cervical spine (22).

The third most prevalent AA variation observed in this study was type V, with a prevalence between 0.13% and 25% (22). Our study findings were higher than that reported in a Korean study (23). The right subclavian artery may run in three ways: coursing to the right behind the esophagus in 80% of cases; between the esophagus and trachea in 15%; anterior to the trachea or mainstem bronchus in 5% of cases. Although generally asymptomatic, it may sometimes be associated with clinical manifestations such as dysphagia (dysphagia lusoria), chest pain, dyspnea, and stridor due to the compression of the trachea and esophagus. Aberrant right subclavian artery can be fatal in symptomatic infants. It may also be life-threatening in patients who require an emergency tracheostomy if it courses anterior to the trachea and in esophagectomy since it crosses the midline posterior to the esophagus on its way to the right arm (15).

Studies have shown that genetic factors also play a critical role in the pathogenesis of AA anomalies. Examples of these are deletions involving the *Fgf8* gene

(24). Several environmental factors, such as maternal medications and vitamin A deficiency in pregnancy, exposure to pesticides, contaminated drinking water, organic pollutants, and toxic metals, have also been found to influence cardiovascular and AA malformations (25).

Conclusion

AA types II, III, and V were the variant branching patterns found in this study. It may be possible that some of our study subjects may have been affected by genetic or environmental factors during prenatal development, resulting in AA variations.

Study limitations

The study was a single-center retrospective study, which limited our sample size compared with similar studies conducted elsewhere.

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