Anatomical Variations in Aortic Arch Branching Pattern: A Computed Tomography Scan Study in Nepalese Population

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ABSTRACT

Introduction: The aortic arch consists of three main branches. And these branches supply the upper limb, head, neck and brain. The knowledge of these anatomical variations is significant for diagnostic, surgical and interventional surgeries of the thorax and neck. Thus, this study aims to know the anatomical variation in the branching patterns of aortic arches among Nepalese population.

Methods: This descriptive study was carried out in the Department of Radiology of Kathmandu Medical College and Teaching Hospital at Sinamangal between 15 November 2024 to 15 February 2025 after getting the ethical clearance from the Institutional Review Committee (reference no. KMC-IRC 16102024/03). The total collection in these three months was 200 after taking the consent verbally. The convenient sampling was done. The study was done in chest CT scan contrast. In this, the variation of the aortic arches was studied under the different Types I to Types VII. The data was analyzed with Statistical Package for the Social Sciences 20 version.

Results: In this study, the maximum distribution of sample was between 56-65 years and 108 (54%) were male and 92 (46%) were female and the most common variation of the aortic arches were the normal that is aortic arches giving rise to the three main branches. However, it was followed by Type II aortic arch second most common among distribution in both genders. In this study the Type III and Type IV was seen in both the gender. But there is no data in Type V, Type VI and Type VII.

Conclusions: The variation in the branches of aorta is crucial in emergency during cardiothoracic surgery. The identification of variation may achieve desired objectives and avoid complications during vascular and intervention surgery.

Keywords- *Artery*, *aortic, arches, surgery.*

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INTRODUCTION

The aorta is the main artery of our body which originates from the heart as the ascending aorta, then continue as the aortic arch and finally ends as the descending aorta. [1] The aortic arch extends from the right to left of the sternal angle and has three main branches: the brachiocephalic trunk, left common carotid artery and left subclavian artery. Further brachiocephalic divides into the right subclavian artery and right common carotid artery. [2]

The variations in the branches of the aortic arches are typically asymptomatic and often can be discovered accidentally during the radiological imaging, autopsy or dissection. [3,4] Some studies suggest that there might be the link between the variations of the branches of the aortic arches and chromosomal abnormalities. [5] The variations can also cause symptoms like dyspnea, dysphagia and other clinical issues. [6]

The knowledge of this is significant for diagnostic, surgical, and interventional surgeries of the thorax and neck. This study aims to know the anatomical variation in the branch of aortic arches among Nepalese population and also to identify the unnoticed variation.

METHODS

This descriptive study was carried out in the Department of Radiology of Kathmandu Medical College and Teaching Hospital at Sinamangal from 15 November 2024 to 15 February 2025. The total collection in these three months was 200 after taking the verbal consent. The chest CT scan of the sample was in between 15-75 years were included. The data was collected after getting the ethical clearance from the Institutional Review Committee (reference no. KMC-IRC 16102024/03). The poor image quality due to motion, artifacts or inadequate distribution of the contrast agent were excluded. Similarly, any history of surgery, trauma and congenital disorder of heart were also excluded.

The sample included all the cases of contrast enhanced CT chest Scan was taken over a period of 3 months. The CT scan was done in Siemens Somatom with 128 slice CT scanner. The contrast agent used was iodinated iohexol. And the image was taken after 40-45 sec after the contrast injected through the intravenous route. For the data analysis, the aortic arches have been classified based on [3]

Type I- Normal, Type II - Bovine Arch, Type III- Left vertebral arises from the arch of aorta

Type IV- Bovine and left vertebral artery, Type V- Common carotid giving rise to the right and left common carotid artery, Type VI- Aberrant Right Subclavian, Type VII- Right arch.

The data was entered in Microsoft Excel and the frequency distribution of the various types of aortic arches were analyzed in different groups of age and gender. The data was analyzed with Statistical Package for the Social Sciences 20 version.

RESULTS

In this study, out of 200 samples, the maximum distribution of sample was between 56-65 years and 108 (54%) were male and 92 (46%) were female as shown in Table 1.

Table 1. General Descriptives of the participants (n=200)

Variables	Frequency (%)
Age interval (years)	
15-25	18 (9%)
26-35	46 (23%)
36-45	31 (15.5%)
46-55	38 (19%)
56-65	59 (29.5%)
66-75	8 (4%)
Gender	
Male	108 (54%)
Female	92 (46%)

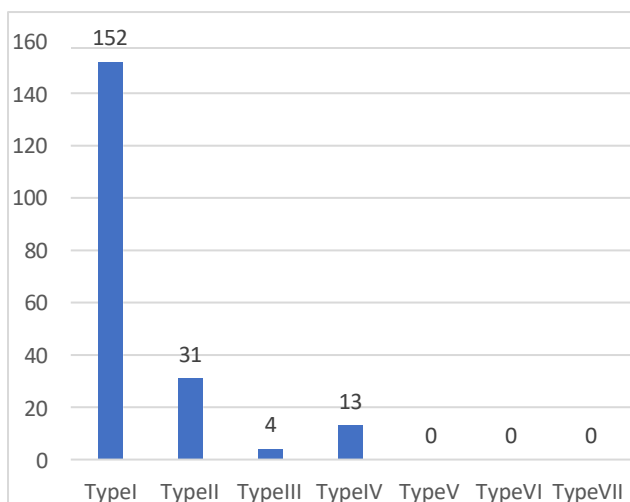The maximum sample were Type I 152 (76%) and followed by Type II arch of aorta as shown in Figure 1.

Figure 1. Distribution of arch of aorta in total participants (n=200)

The distribution of types of aortic arch showed that Type I aortic arch distribution was most prevalent in both the male (79.6%) and female (71.7%) as shown in Table 2. This was followed by Type II aortic arch distribution in both genders.

Table 2. Distribution of aortic arch in different gender (n=200)

Gender	Arch of Aorta						
	Type I n(%)	Type II n(%)	Type III n(%)	Type IV n(%)	Type V n(%)	Type VI n(%)	Type VII n(%)
Male	86(79.6)	13(12)	3(2.8)	6(5.6)	0	0	0
Female	66(71.7)	18(19.6)	1(1.1)	7(7.6)	0	0	0

DISCUSSION

Normally, the aortic arches consist of the three Major branches. The aortic arch is a large artery supplying blood to the head, neck, and upper limbs. The branches of the aortic arches are the brachiocephalic trunk, left common carotid artery and left subclavian artery. The variations in the branching pattern of the aortic arch are relatively common and often it undergoes unnoticed. The variation in the branches of the aortic arches are typically asymptomatic. These variations might refer to make the differences in the blood flow according to the way blood vessels branch out from the aortic arch to supply blood to various structures including the head, neck, and upper limbs. The variation is discovered accidentally during routine diagnostic imaging procedures such as CT scans of chest, MRIs of thorax, or angiograms which is

performed for other medical conditions. During interventional procedures like catheterizations, angiographies and the placement of stents, knowing the variation and the vascular anomalies in the aortic arch beforehand would prevent it from complication. It is said that chest CT scan contrast can be considered as an essential tool in the diagnosis and evaluation of aortic arch variation. It has numerous advantages such as short duration and good view for observing the anatomic variation in the aortic arches.[7]

Whereas, the Aortic arch variations are classified based under the anatomical and morphologic features of the aorta which includes the side of the arch of aorta, course of the aorta, and various branching pattern of aorta. [8] This variation is important to recognize, especially during the clinical approach, surgical planning, diagnostic procedures and also for understanding various vascular diseases. [9]

In this study, the normal variation of the branches of aortic arches was maximum in both the male and female 86 (79.6%) and 66 (71.7%) respectively. The numerous studies have been conducted on the variation in the branching pattern of the aortic arches. The study done by Murray A and Meguid E.A came with normal branching pattern of aortic arches was (61.2– 92.59%) and bovine arch Type I (4.95–31.2%) which supports this research. [10] The study done in Peruvian population also came with the conclusion that 282 patients (78.12%) had a normal aortic arch branch (Type I; aortic arch

giving rise to the brachiocephalic trunk, left common carotid and left subclavian artery). [11] Some authors also came with the conclusion that the variations in Aortic arches branching pattern plays important role for the endovascular aortic arch repair, aortic stent, grafts which need to be modified according to the variations in branches of the Aortic arches. In their study also the normal anatomy of branches of the aortic arches were maximum and second common was the Type-II. [12] Some study also stated that the incidence of acute stroke was significantly higher among patients with a bovine arch compared with those with a non-bovine arch. [13] It is also said that knowing the bovine aortic arch before an endovascular procedure and any other surgery of head and neck will minimizes the complications and also shortens the duration of the procedure. [14] The improvements in antenatal ultrasound technology and advanced equipment have enhanced the detection rate of Bovine Aortic Arches during prenatal screening. Despite increased early detection, some authors also claimed that there remains a significant shortage of literature regarding chromosomal abnormalities which is linked to fetal Bovine Aortic Arch and the associated clinical outcomes. [15,16],

This study also identified the presence of the Type IV that was the bovine aortic arch and a left vertebral artery originating directly from the aortic arch. However, a study done by Mylonas, Spyridon N et al. also showed the Type IV aortic

arches in their study. [17]

However, the less common variation observed in this study for both genders was Type III which was found in 3 males (2.8%) and females 1(1.1%). In this study Type III means the left vertebral artery arises from the directly from the arch of aorta. The study which was done to see the branching patterns of the aortic arch in 25 anatomical specimens were observed that only 1 variation (4%) were taking origin of the left vertebral artery directly from the aortic arch. According to some authors, the aberrant branch of the aortic arch was forming as a fourth artery which was located in between left subclavian artery and the left common carotid artery. In that study, also the least one was the Type III which supports this study. [18] However, some authors claimed that approximately 6% of the population had the left vertebral artery taking origin directly from the arch of aorta usually which is located in between left subclavian artery and the left common carotid artery. [19] Some authors have reported that there is a significant tendency for the emboli to preferentially affect the left cerebral hemisphere in individuals with a Bovine Aortic Arch variant. [20]

Whereas, embryologically, the development of the aorta arches takes place during the third week of gestation period. [21] Development of the aortic arches is considered as the complex process which is associated with the formation of the endocardial tube. Each primitive aorta consists of a ventral and a dorsal segment that are continuous through the first aortic arch. The two-ventral segment of the aorta fuse together and form the aortic sac. [22] The aortic sac is regarded as the initial part of the formation of aorta and it is located superior to the truncus arteriosus. The aortic sac subsequently develops into two horns that are the right and left horns. Developmentally, the right horn gives rise to the brachiocephalic trunk. The aortic arches develop from the aortic sac and proceed into the pharyngeal arches. The aortic sac gives rise to six pairs of aortic arch arteries. Out of that, the fifth pair appears and one pair disappears. Hence, according to that the five aortic arch arteries are numbered as I, II, III, IV, and VI. The right subclavian artery arises from proximal part from right fourth arch artery and distal part from right seventh cervical intersegmental artery. Whereas left subclavian artery arises from left seventh cervical intersegmental artery. And the external carotid artery arises from the third arch artery. The common carotid artery arises from third arch artery which is located proximal to the external carotid artery bud. The internal carotid artery developed from third arch artery located distal to the external carotid bud and also from cranial part of dorsal aorta distal to the attachment of third arch artery. Ultimately, the Arch of aorta develops from the Aortic sac, left horn of aortic sac and left fourth arch artery. [23] It was said that in the third week of gestation, during the development of heart is the complicated process occurs in the development of the aorta while formation of the endocardial tube which may lead to the congenital aberrant branching patterns of the aortic arch. [24]

Some authors also claimed that the variation in the branches of the aortic arches can be due to that

deletion of chromosome 22q11which is associated with such aortic arch anomalies. [25] Some authors suggest that the variation in the origin of the vertebral arteries can lead to the intracerebral disorders by altering vascular hemodynamics, as it led to the unstable blood flow from the aortic arch to the cerebral hemisphere which might increase the risk of ischemia, occlusion, thrombosis, atherosclerosis and aneurysm. [26,27] And also, in this study there was no data recorded in Type V, VI and VII.

Limitation of this study, it would be more effective if the sample size were more and with longer study duration period. This study was fully focused on anatomical variations and did not explore the functional significance of these variations in the branching pattern of Aortic arches. Future studies should investigate whether these variations correlate with clinical conditions or influence the risk of certain cardiovascular diseases and also risk for cerebral hemisphere. The study did not include a comparative analysis between different ethnic groups with the variation of the branching pattern of Aortic arches. This study would have been great with comparison of variation of the aortic arches in relation to the different ethnicity of Nepal.

CONCLUSIONS

The concept of variations of the aortic arch branches is crucial in emergency during cardiothoracic surgery and neck surgery. The variation in the branching patterns of the aortic arch play important role during aortic instrumentation, angiographies or head and neck surgery. Before during the surgery, the surgeon must be aware about the variations in the branching pattern of the major arteries and should be able to identify them. The identification in variation may achieve desired objectives and avoid complications during vascular surgery. The present study highlights the anatomical variations of the aortic arch and their clinical relevance. Our findings demonstrate normal anatomy of the branches of the aortic arches Type I were maximum along with the Type II followed by Type IV in both the gender.

CONFLICT OF INTEREST

None

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REFERENCES

1. Kumar A, Mishra A. Anatomical variations in the branching pattern of human aortic arch: a cadaveric study from Nepal. Eur J Anat. 2015;19:43–7. [Full Text]

2. Boggs RA, Romp RL. Persistent Fifth Aortic Arch Confirmed by Computed Tomography Angiography. World J Pediatr Congenit Heart Surg. 2015 Oct;6(4):670-1. [PubMed | DOI]

3. Popieluszko P, Henry BM, Sanna B, et al. A systematic review and meta-analysis of variations in branching patterns of the adult aortic arch. J Vasc Surg. 2018;68:298–306. [PubMed | DOI]

4. Ergun O, Tatar IG, Birgi E, Durmaz HA, Akcalar S, Kurt A, Hekimoglu B. Angiographic evaluation of branching pattern and anatomy of the aortic arch. Turk Kardiyol Dern Ars. 2015;43:219–226. [PubMed | DOI]

5. Reinshagen L, Vodiskar J, Muhler E, Hovels-Gurich HH, Vazquez-Jimenez JF. Bicarotid trunk: how much is "not uncommon"? Ann Thorac Surg. 2014;97(3):945–49.

6. Karacan A, Turkvatan A ,Karacan K. Anatomical variations of aortic arch branching: evaluation with computed tomographic angiography. Cardiology in the Young. 2014;24(3):485-93. [PubMed | DOI]

7. Baz RO, et al. CT Angiography for Aortic Arch Anomalies: Prevalence, Diagnostic Efficacy, and Illustrative Findings. Diagnostics (Basel). 2024;14(17):1851. [PubMed | DOI]

8. Kellenberger CJ. Aortic arch malformations. Pediatr Radiol. 2010;40:876–84. [PubMed | DOI]

9. Bae SB, Kang EJ, Choo KS, et al. Aortic Arch Variants and Anomalies: Embryology, Imaging Findings, and Clinical Considerations. J Cardiovasc Imaging. 2022;30(4):231-62. [PubMed | DOI]

10. Murray A, Meguid EA. Anatomical variation in the branching pattern of the aortic arch: a literature review. Ir J Med Sci. 2023;192(4):1807-17. [PubMed | DOI]

11. Huapaya JA, et al. Anatomic variations of the branches of the aortic arch in a Peruvian population. Medwave. 2015;15(6): e6194. [PubMed | DOI]

12. Chassin-Trubert L, Gandet T, Ozdemir BA, Lounes Y, Alric P, Canaud L. Aortic Arch Anatomy Pattern in Patients Treated Using Double Homemade Fenestrated Stent-Grafts for Total Endovascular Aortic Arch Repair. J Endovasc Ther. 2020;27(5):785-91. [PubMed | DOI]

13. Lo Russo GV, Alarouri HS, Al-Abcha A, et al. Association of Bovine Arch Anatomy with Incident Stroke After Transcatheter Aortic Valve Replacement. J Am Heart Assoc. 2024;13(4):e032963. [PubMed | DOI]

14. Malone CD, Urbania TH, Crook SE, Hope MD. Bovine aortic arch: A novel association with thoracic aortic dilation Clin Radiol. 2012;67:28–31. [PubMed | DOI]

15. Goldsher YW, Salem Y, Weisz B, Achiron R, Jacobson JM, Gindes L. Bovine aortic arch: prevalence in human fetuses. J Clin Ultrasound. 2020;48(4):198–203. [PubMed | DOI]

16. Ples L, Cirstoveanu C, Sima RM, et al. Prenatal diagnosis of bovine aortic arch anatomic variant. Diagnostics (Basel). 2022;12(3):624. [PubMed | DOI]

17. Mylonas SN, Barkans A, Ante M, Wippermann J, Bockler D, Brunkwall JS. Prevalence of Bovine Aortic Arch Variant in Patients with Aortic Dissection and its Implications in the Outcome of Patients with Acute Type B Aortic

Dissection. Eur J Vasc Endovasc Surg. 2018;55(3):385-91. [PubMed | DOI]

18. Onrat E, Uluisik E, Ortug G. The left vertebral artery arising directly from aortic arch. Translational Research in Anatomy. 2021;24. [FullText]

19. Rosen RD, Bordoni B. Embryology, Aortic Arch. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Mar 6. [PubMed]

20. Matakas JD, et.al. Bovine Arch and Stroke Laterality. J Am Heart Assoc. 2020;9: e015390 [FullText]

21. Schleich J M. Images in cardiology— development of the human heart: days 15–21. Heart. 2002;87:487. [PubMed | DOI]

22. Kau T, Sinzig M, Gasser J, et al. Aortic development and anomalies. Semin Intervent Radiol. 2007;24(2):141-52. [PubMed | DOI]

23. Koenigsberg, et al. Unusual vertebral artery origins: Examples and related pathology. Catheter Cardiovasc Interv.2003;59:244-50. [PubMed | DOI]

24. Kau T, Sinzig M, Gasser J, et al. Aortic development and anomalies. Semin Intervent Radiol. 2007;24(2):141-52. [PubMed | DOI]

25. Momma K, Matsuoka R, Takao A. Aortic arch anomalies associated with chromosome 22q11 deletion (CATCH 22). Pediatr Cardiol. 1999;20(2):97-102. [PubMed | DOI]

26. Magklara EP, Pantelia ET, Solia E, et al. Vertebral artery variations revised: Origin, course, branches and embryonic development. Folia Morphol (Warsz) 2021;80(1):1–12. [PubMed | DOI]

27. Berko NS, Jain VR, Godelman A, et al. Variants and anomalies of thoracic vasculature on computed tomographic angiography in adults. J Comput Assist Tomogr. 2009;33(4):523–28. [PubMed | DOI]