Journal of Clinical and Medical Images

Case Report

ISSN: 2640-9615 | Volume 8

Variations In the Branching Pattern of Aortic Arch and Its Clinical Correlation A Computed Tomographic Angiographic Study

Yashu Bhardwaj[1], Brijendra Singh[2], Rashmi Malhotra[3], Pankaj Sharma[4*], and Rahul Sharma[5]

[1]Department of Anatomy, All India Institute of Medical Sciences, Rishikesh, Uttarakhand

[2]Department of Anatomy, All India Institute of Medical Sciences, Rishikesh, Uttarakhand

[3]Department of Anatomy, All India Institute of Medical Sciences, Rishikesh, Uttarakhand

[4]Department of Radiodiagnosis, All India Institute of Medical Sciences, Rishikesh, Uttarakhand

[5]Department of Anatomy, All India Institute of Medical Sciences, Rishikesh, Uttarakhand

[*]Corresponding author:

Pankaj Sharma,

Department of RadiodiagnosisAll India Institute of Medical Sciences, Rishikesh, Uttarakhand

Received: 21 Feb 2025

Accepted: 02 Mar 2025

Published: 07 Mar 2025

J Short Name: JCMI

Citation:

Pankaj Sharma, Variations In the Branching Pattern of Aortic Arch and Its Clinical Correlation A Computed Tomographic Angiographic Study. J Clin Med Img. 2025; V8(7): 1-8

Keywords:

Aortic Arch; Variations; Computed Tomography; Brachiocephalic Trunk; Common Carotid Artery

Abbreviations:

AA:Aortic Arch; CTA:Computed Tomography Angiography; LCCA:Left Common Carotid Artery; RCCA:Right Common Carotid Artery; TIA:ThyroideaIma Artery; BCT:Brachiocephalic Trunk; LVA:Left Vertebral Artery; RVA:Right Vertebral Artery; LSA:Left Subclavian Artery; RSA:Right Subclavian Artery

1. Abstract

1.1. Background

Variations in branching pattern of aortic arch (AA) can occur, due to it's complex embryological development. These variations are quite common, and typically asymptomatic; but can sometimes cause dyspnea, dysphagia, intermittent claudication, and/or confusion in interpretation of radiological scans. Methods: The types and incidence of aortic arch variations in 105 patients were analyzed after careful computed tomographic imaging.

1.2. Results

In present study, 3 patients with variations in branching pattern had experienced dyspnea (15%). Left common carotid artery (CCA) had origin from brachiocephalic trunk (BCT) in 8 (40%) participants. Left vertebral artery (VA) had origin from aortic arch (AA) in 5 (25%) participants. Thyroid Ima artery (TIA) had origin from BCT in 2 (10%) participants. Left CCA and BCT had origin from AA as single Trunk in 2 (10%) participants. Left VA had origin from AA, and Right VA had origin from BCT in total 1 (5%) participant; BCT had origin as last Left branch from AA in 1 (5%) participant; right and left CCA had origin as single trunk from AA in 1 (5%) participant.

1.3. Conclusion

Present study is first prospective study done in Himalayan belt of North India, and highlights importance of spreading awareness about variations in branching pattern of aortic arch; which is useful for executing endovascular procedures, and helps in planning cardiothoracic surgeries.

2. Introduction

AA gives three main branches: a) Left common carotid artery (LCCA), b) Left subclavian artery (LSA),and c) brachiocephalic trunk (BCT) from left to right respectively; BCT gives rise to right subclavianartery (RSA),and right common carotid artery (RCCA); and Vertebral artery (VA) arises from each individual subclavian artery. Because the AA and its branches form in a complicated way during embryogenesis, deviations from normal branching patterns are quite common, and typically asymptomatic; and become apparent only when a patient undergoes imaging/surgery/autopsy [1]. Because of aberrant fetal AA involutions, anatomical abnormalities of AA typically manifest in first and second trimester. Six pairs of AA arise from ventral and dorsal aorta; and fifth pair totally vanishes during fetal development. Remaining AA divide into distinct arteries that give supply to lungs, upper limbs, head, and neck region following delivery. Adult AA is typically formed from remaining left fourth AA, with its usual branches [2].Numerous chromosomal anomalies have been associated with anatomical variations of AA branches. At least one congenital heart abnormality is present in up to 98.4% of pediatric patients, with bovine AA. Reported incidence is up to 35%, among those with Down syndrome; and indicates that anomalous RSA is a biomarker for Down syndrome and associated cardiac problems [1].Although in large cohort studies RSA as a biomarker for trisomies has not been confirmed.More population based morphometric investigations are necessary, despite the fact that anatomical variations are only found in a small percentage of cases. These studies are necessary because of significant useful impact, and potential for regional and ethnic variations [2]. Till date, there is no data available about the AA branching pattern, from Himalayan belt of North India. Purpose of this study is to characterize the variations in branching pattern of AA, which provides useful information to anatomist, radiologist, vascular surgeon, neck, and thoracic surgeon in North India. Even though, most of these anatomical variants are typically asymptomatic; few of these anatomical variants can result in dyspnea, dysphagia, intermittent claudication and/or confusion in interpretation of radiological scans, along with difficulty during neck and thoracic surgery. These insight are quite helpful, when surgeons utilize devices to breach the AA, and it's branches.

3. Aim and Objective

This prospective observational study aimed to investigate the normal anatomy and variations in the branching pattern of the aortic arch, within the adult population of North India's Himalayan region.The participants were selected from Radiodiagnosis Department of All India Institute of Medical Sciences, Rishikesh.

4. Material and Method

Present study was done prospectively in Department of Anatomy, in collaboration with Department of Radiodiagnosis, All India Institute of Medical Sciences, Rishikesh, within period of 18 months. 105 participants above age of 18 years were included, and all participants underwent Computed Tomographic Angiography (CTA). Patients who had undergone previous CCA occlusion, or who had known vascular abnormality (carotid hypoplasia, or plaque in carotid bifurcation, or aneurysm in neck/thoracic vessels), were excluded. Following the approval of Institutional Ethics Committee (IEC), with ethical clearance number AIIMS/IEC/21/323, CTA data from 64slice computed tomography (CT) scanner, or 128slice CT scanner was collected. Reconstruction of three dimensional view of CT images was done using RadiAntDicom Viewer (RadiAnt©), software installed in MSI laptop PC. The images thus obtained were observed, and evaluated for AA variations. The images were analyzed as per the general anatomical course and braches of AA vessels, and variations if any were noted. Statistical analysis was done using Chi Square test, and Stuart Maxwell test.

5. Observation and Result

According to study done by [3], there are seven different types of variations found in AA :

a) Type 1, Normal: AA gives following branches from right to left - BCT, LCCA, and left subclavian artery (LSA).

b) Type 2, Bovine arch: AA gives following branches from right to left- a common stem that gives rise to BCT, LCCA, and LSA.

c) Type3, Left vertebral: AA gives following branches from right to left - BCT, LCCA, left vertebral artery (LVA), and LSA.

d) Type 4, Bovine and LVA: AA gives following branches from right to left - a common trunk of BCT and LCCA from AA, followed by LVA and LSA.

e) Type 5, Common Carotid: AA gives following branches from right to left – RSA, and a common trunk for RCCA, LCCA, and LSA.

f) Type 6, Aberrant RSA: AA gives following branches from right to left – RCCA, LCCA, LSA, and an aberrant RSA.

g) Type 7, Right arch: AA extends from left to right, releasing a "mirrored" pattern or aberrant LSA.

In present study, out of total 105 participants, we found that 85 participant scans were type 1 (Normal) (80.95%); while we could pick variations in AA in 20 participant's CT scan (Figure 1,2,3,4,5,6). 8 participants had type 2 (Bovine arch) (7.61%); 5 participants had type 3 (Left Vertebral) (4.76%); 1 participant had type 5 (Common carotid) (0.95%); 1 participant had type 7 (Right arch)AA (0.95%).

However, other than variations described by Popieluszko et al, we could also found additional variations (Table 1):

a) 2 participants had LCCA originating as a common trunk with BCT (1.90%).

b) 2 participants had thyroid ima artery (TIA)arising from BCT (1.90%).

c) 1 participant had right vertebral artery (RVA) branching from BCT, and LVA branching directly from AA (0.95%).

LCCA had origin from BCT in 8 (40%) participants; LVA had origin from AA in 5 (25%) participants; TIA had origin from BCT in 2(10%) participants; LCCA and BCT had origin from AA as Single Trunk in 2(10%) participants; LVA had origin from AA, and RVA had origin from BCT in total 1 (5%) participant; BCT had origin as last left branch from AA in 1 (5%) participant; RCAA and LCCAhad origin as single trunk from AA in 1 (5%) participant.Fisher's exact test was used to explore the association between 'Gender' and 'Variation in branching pattern' as more than 20% of total number of cells had an expected count of less than 5.There was no significant difference between the various groups in terms of distribution of variation in branching pattern ($\chi2 = 7.769$, $p = 0.188$). Strength of association between the two variables (Cramer's V) = 0.64 (High Association). Strength of association between the two variables (Bias Corrected Cramer's V) = 0.28 (Low Association). LCCA had origin from BCT in 54.6% of participants in group [Gender: Male]; LVA had origin from AA in 36.4% of participants in group [Gender: Male]; TIA had origin from BCT in 10% of participants in group [Gender: Male]; BCT was last left branch from AA in 0.0% of participants in group [Gender: Male]; LCCA and BCT had origin from AA as single trunk in 0.0% of participants in the group [Gender: Male]; LVA had origin from AA, RVA had origin from BCT in 0.0% of participants in group [Gender: Male]; and 0.0% of participants in group [Gender: Male] had variation: origin of BCTalong with LCCA as single trunk from AA (Table 2).LCCA had origin from BCT in 22.2% of participants in group [Gender: Female]; LVA had origin from AA in 11.1% of participants in group [Gender: Female]; BCT as last left branch from AA in 11.1% of the participants in group [Gender: Female]; LCCA and BCT had origin from AA as single trunk in 11.1% of participants in group [Gender: Female]; LVA had origin from AA, RVA had origin from BCT in 11.1% of participants in group [Gender: Female]; Origin of BCT along with LCCA as single trunk from AA in 11.1% of participants in group [Gender: Female]; TIA had origin from BCT in 11.1% of participants in group [Gender: Female]; RCCA and LCCA had origin as single trunk from AA in 11.1% of participants in group [Gender: Female].

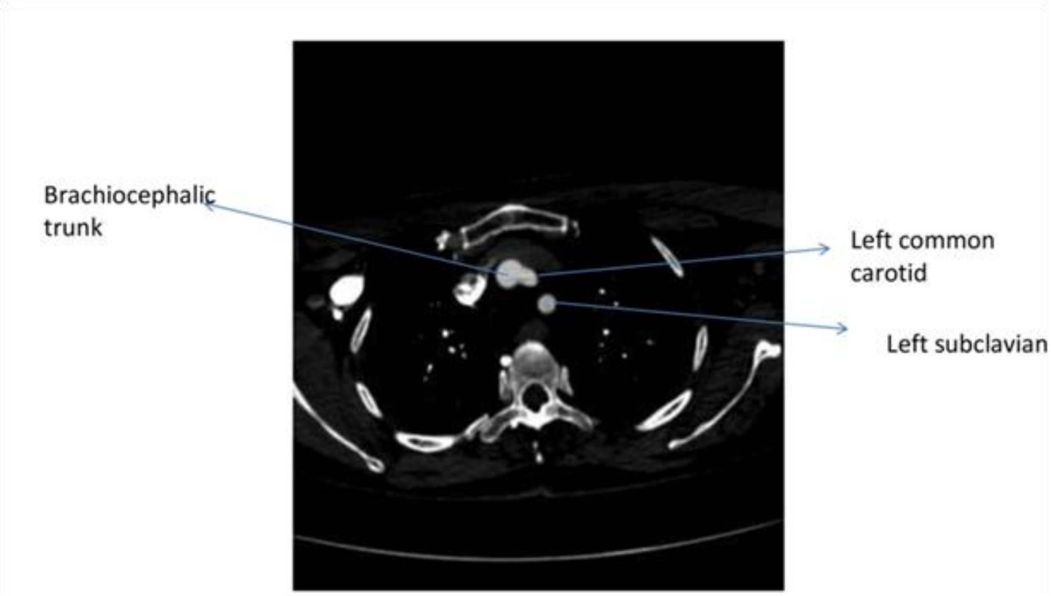

Figure 1: Left common carotid artery (CCA) arises from brachiocephalic trunk (BT).

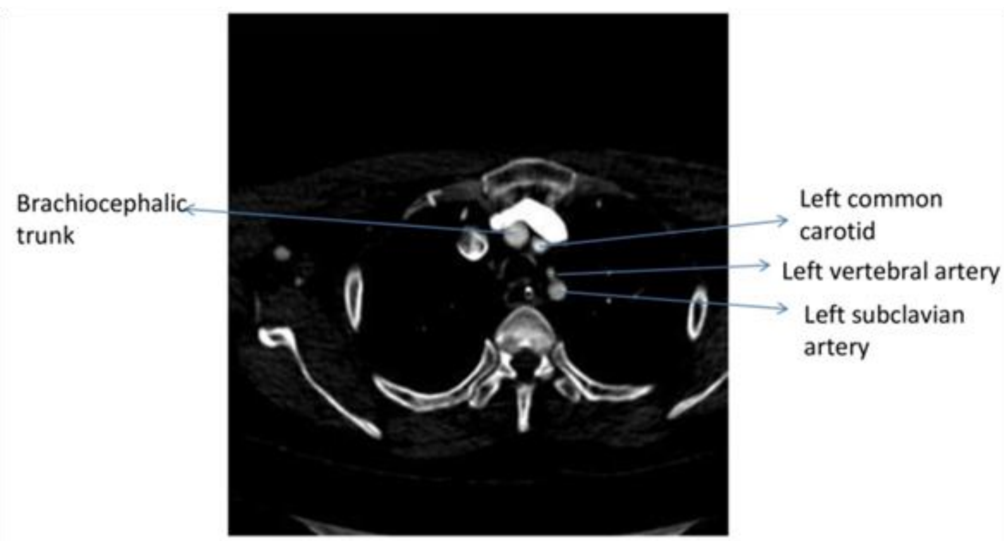

Figure 2: Left vertebral artery (VA) arises from arch of aorta.

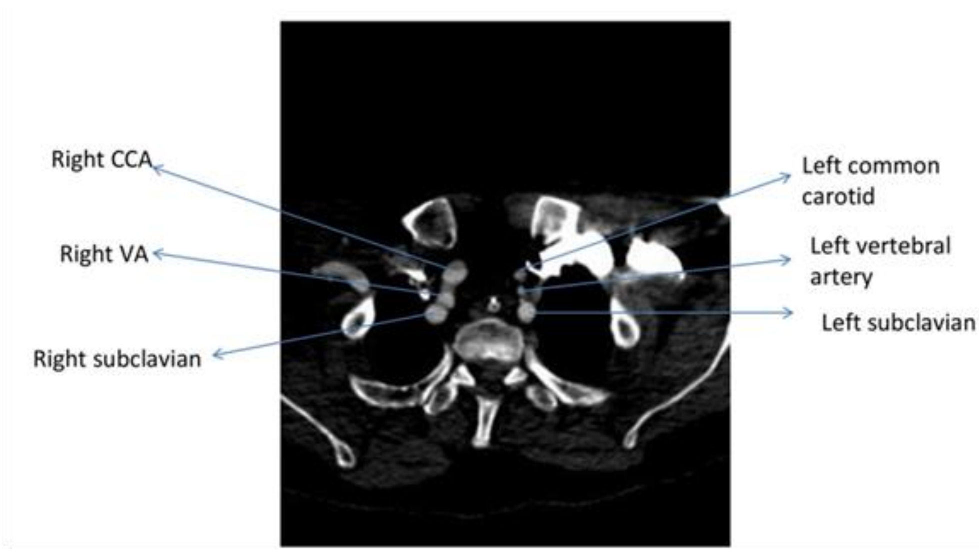

Figure 3: Right vertebral artery (VA) originates from brachiocephalictrunk (BT). Left vertebral artery arise from arch of aorta.

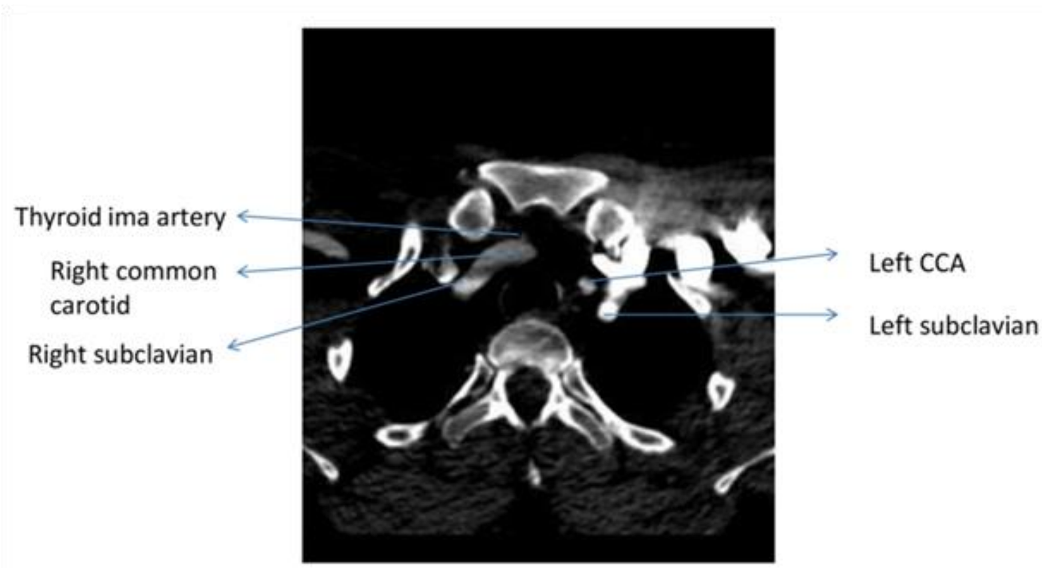

Figure 4: Thyroid imaartery (TIA) arises from brachiocephalic trunk (BT).

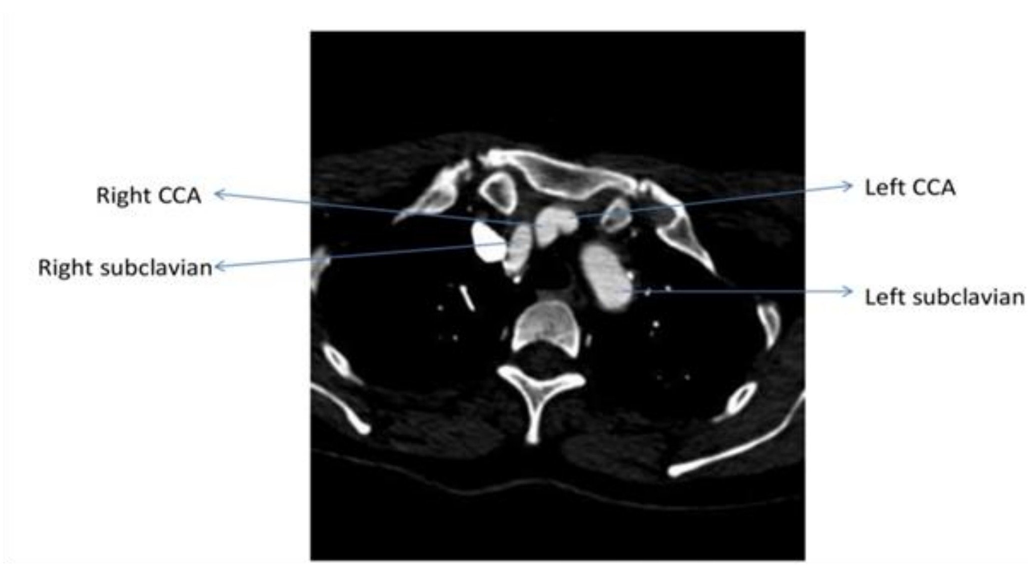

Figure 5: left and right common carotid artery (CCA) arises from arch of aorta as single trunk.

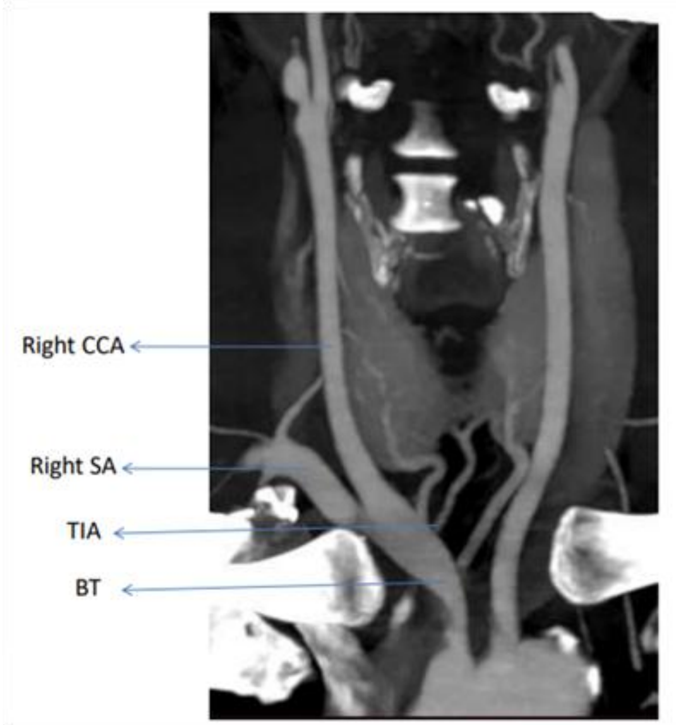

Figure 6: Thyroid Ima artery (TIA) is originating from brachiocephalic (BCT) trunk.

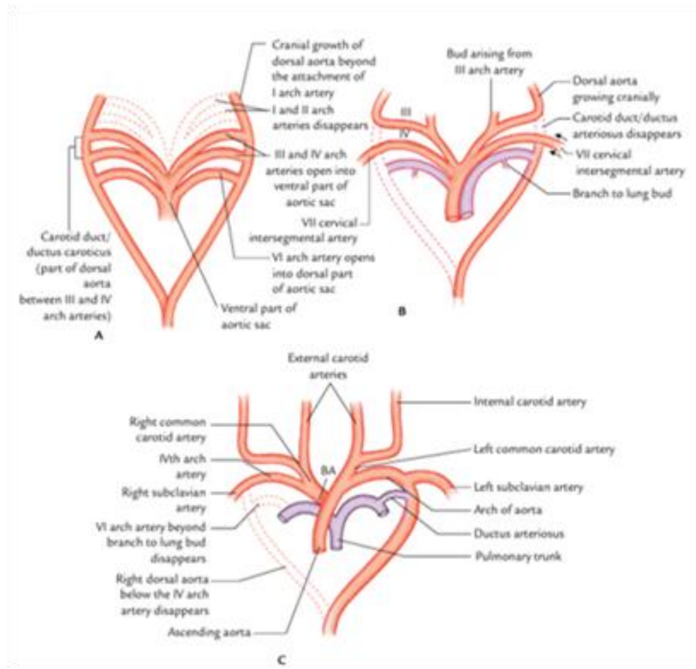

Figure 7: Development of aortic arches.

Table 1: Distribution of Participants in Terms of Variation in branching pattern (n = 20).

Variation in branching pattern	Frequency	Percentage	95% CI
Left CCA Arises From BCT	8	40%	25.2% - 70.5%
Left VA Arises From AA	5	25%	10.1% - 51.4%
Left CCA and BCT Arise from AA As Single Trunk	2	10%	0.3% - 28.1%
TIA from BCT	2	10%	0.3% - 28.1%
Left VA Arises From AA, Right VA Arise From BCT	1	5%	0.3% - 28.1%
BCT Arises As Last Left Branch From AA (Right Arch)	1	5%	0.3% - 28.1%
Right and left common carotid artery arises as single trunk from AA	1	5%	0.3% - 28.1%

Table 2: Association between Gender and variations observed.

Variation in branching pattern	Gender			Fisher's Exact Test	
	Male	Female	Total	χ2	P Value
Left CCA Arises From BCT	6 (54.6%)	2 (22.2%)	8 (40%)	7.769	0.188
Left Vertebral Artery Arises From AA	4 (36.4%)	1 (11.1%)	5 (25%)		
Thyroid Ima Artery from BCT	1(10%)	1(11.1%)	2 (10%)		
Left CCA And BCT Arise From AA As Single Trunk	0 (0.0%)	1 (11.1%)	1 (5%)		
Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT	0 (0.0%)	1 (11.1%)	1 (5%)		
Origin Of BCT Is Along With Left CCA As Single Trunk From AA	0 (0.0%)	1 (11.1%)	1 (5%)		
BCT Arises As Last Left Branch From AA	0 (0.0%)	1 (11.1%)	1 (5%)		
Right and left common carotid artery arises as single trunk from AA	0 (0.0%)	1 (11.1%)	1 (5%)		
Total	11 (100.0%)	9 (100.0%)	20 (100.0%)		

Variation in branching pattern	Adjusted P Values
Left CCA Arises From BCT vs. Left Vertebral Artery Arises From AA	1.000
Left CCA Arises From BCT vs. BCT Arises As Last Left Branch From AA	0.840
Left CCA Arises From BCT vs. Left CCA And BCT Arise From AA As Single Trunk	0.840
Left CCA Arises From BCT vs. Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT	0.840
Left CCA Arises From BCT vs. Origin Of BCT Is Along With Left CCA As Single Trunk From AA	0.840
Left CCA Arises From BCT vs. Thyroid Ima Artery from BCT	0.840
Left Vertebral Artery Arises From AA vs. BCT Arises As Last Left Branch From AA	0.840
Left Vertebral Artery Arises From AA vs. Left CCA And BCT Arise From AA As Single Trunk	0.840

Variation in branching pattern	Adjusted P Values
Left Vertebral Artery Arises From AA vs. Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT	0.840
Left Vertebral Artery Arises From AA vs. Origin Of BCT Is Along With Left CCA As Single Trunk From AA	0.840
Left Vertebral Artery Arises From AA vs. Thyroid Ima Artery from BCT	0.840
BCT Arises As Last Left Branch From AA vs. Left CCA And BCT Arise From AA As Single Trunk	1.000
BCT Arises As Last Left Branch From AA vs. Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT	1.000
BCT Arises As Last Left Branch From AA vs. Origin Of BCT Is Along With Left CCA As Single Trunk From AA	1.000
BCT Arises As Last Left Branch From AA vs. Thyroid Ima Artery from BCT	1.000
Left CCA And BCT Arise From AA As Single Trunk vs. Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT	1.000
Left CCA And BCT Arise From AA As Single Trunk vs. Origin Of BCT Is Along With Left CCA As Single Trunk From AA	1.000
Left CCA And BCT Arise From AA As Single Trunk vs. Thyroid Ima Artery from BCT	1.000
Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT vs. Origin Of BCT Is Along With Left CCA As Single Trunk From AA	1.000
Left Vertebral Artery Arises From AA, Right Vertebral Artery Arise From BCT vs. Thyroid Ima Artery from BCT	1.000
Origin Of BCT Is Along With Left CCA As Single Trunk From AA vs. Thyroid Ima Artery from BCT	1.000

6. Clinical Correlation

During followup with participants, who had variations in branching pattern of AA; we found that 15% of participants experienced dyspnea, and no other probable cause for dyspnea was found on further investigation.

7. Discussion

Kodikara I et al. [2], in 2022 studied CT branching pattern of AA in Sri Lankan population, and found that four forms of AA were identified: type 1 (n = 197, 90%), type 2 (n = 10, 4.6%), type 3 (n = 8, 3.7%), and type 6 (n = 4; 1.8%); with only 10% of participants showing AA variations. In both genders, type 1 AA was most common pattern (91% in females, 88.9% in males). For females, type 2 (n = 6; 5.4%) was the most common AA variation; and for males, type 3 (n = 5; 4.6%) was the most common AA variation. But there was no evidence of significant gender influence on AA branching pattern (odds: 0.792; 95% CI: 0.327–1.917; p=0.605). The negative effects of vascular examinations and therapies could be reduced if a community was aware of the frequency of surgically and angiographically significant arch alterations.While in present study, we found 5 type of branching pattern of AA among 19.5% of participants; type 1 (n = 85; 80.95%), type 2 (n = 8; 7.62%), type 3 (n =5; 4.76%), type 5 (n = 2; 0.95%) and type 7 (n = 1; 0.95%). Additionally, we found following AA variations: 2 participants had LCCA originating as a common trunk with BCT; 2 participants had TIA arising from BCT; and 1 participant had RVA branching from BCT and LVA branching directly from AA.Patil ST et al. [4], did a study on 75 cadavers in Nagpur belt of India, and found that the usual 3 branched aortic arch was seen in 58 (77.3%) cadavers; 11 (14.66%) cadavers showed 2 branches from aortic arch, one being common trunk for origin of BCT and LSCA, and second being origin of LSCA; and 6 (8%) cadavers showed LVA arising directly from AA, with aortic arch branches being BCT, LCCA, LVA and LSA from left to right. Understanding the various aortic arch patterns is essential when inserting equipment into the fragile aortic arch and its branches.Pandalai U et al. [5],in 2021 dida study on 4,000 participants from South Indian population, to see the anatomical variation of AAon CT scan (with contrast). These patients showed 27 different variations of AA: 7 participants had an aberrant RSA; 1 participant had bovine arch;1 participant had bovine origin of LVA artery from AA;1 participant had anomalous bronchial artery from AA; 1 participant had double AA; and 16 participants had right sided AA. Imaging should be done before any procedure involving vascular access, given the prevalence seen in this study, to avoid problems. To determine the burden of aortic arch variation in the population, more research is necessary, particularly with regard to individuals from the Indian subcontinent. In present study, we found that 85 participants CTA scans were normal, while variations in AA were seen in 20 participants; out of which 8 participants had Bovine arch, 5 participants had LVA arising from AA, 1 participant had origin of RCCA and LCCA as single trunk from AA; and 1 participant had Right AA. Additionally, we found following AA variations:2 participants had LCCA originating as a common trunk with BCT;2 participants had TIA arising from BCT; and 1 participant had RVA branching from BCT and LVA branching directly from AA.Aboulhoda BE et al. [6],in 2019 studied variations in AA by CTA in Egyptian population, and found that «Bovine arch» was most prevalent abnormal branching pattern, accounting for 24% of investigated AA. 6% of participants had common ostium variant, and 5% of participants had aberrant LVA emerging straight from AA. Specifically for patients undergoing aortic endovascular intervention, the shown anatomical variances and morphometric data give crucial information, primarily for selecting the size, shape, and type of angiographic catheters and devices to be supplied.Mustafa AG et al. [7], in 2017 did a CTA study on branching pattern of AAin Jordanian population, and found six artery arrangement (based on origin of arteries fromAA). Typical classical pattern was most prevalent pattern seen in 61.2% of participants. AA variations were seen in remaining (38.8%) participant; and six categories were used to classify AA variations. No significant relationship was found between sex, and prevalence of AA variations. Regarding the frequency of aortic arch branching variations among Jordanians, this study offers fresh data. There were numerous structural differences seen in the aortic arch's branching pattern. Angiography, aortic instrumentation, and supra-aortic thoracic, head, and neck surgery should all take this into account.In a cadaveric study on variation of branching pattern of AA in North Maharashtra region8, it was found that 59 cadavers (89.39%) had three branched AA; 5 cadavers (7.57%) had only two branches, one of these branches was common trunk that included LCCA, BCT, and LSA; other 2 cadavers (3.33%) had direct origin of LVA from AA [9].In 2014, CTA study was conducted on 1,000 participants from Turkish population, to study branching pattern of AA.9 It was found that 79.2% of participants had normal branching pattern (type 1), and 20.8% of participants had variations in AA. 14.1% participants had type 2 branching pattern (BCT and LCCA arising as common trunk from AA); 4.1% participants had type 3 branching pattern (LVA arising from AA); 1.2% participants had type 4 branching pattern (coexistence of type 2 and type 3); 0.6% participants had type 5 branching pattern (aberrant RSA);0.7% participants had type 6 branching pattern (coexistence of anomalous RSA and bicarotid trunk); and 0.1% participants had type 7 branching pattern (TIA originating from AA). Incidence of AA branching variation was similar, both in men and women (20% vs. 22.1%). It is critical to recognize abnormalities in the branching of the aortic arch because they may result in symptoms from compression of the tracheoesophageal tube or complications from surgery or endovascular intervention on the aorta and its branches.Our study was a single centre study, and had limitation that only 105 participants could be recruited, and that too from limited geographical region. Multicentre study should be done involving participants from widespread geographical region, to reach a meaningful conclusion, with wider implications in clinical practice.

8. Conclusion

Variations in branching pattern of AA are quite common, and have widespread clinical implications, ranging from planning endovascular interventions, for executing cardiothoracic surgeries. 19.5% of participants in this study had AA variations.Nowadays, comprehensive preoperative CTA examination of neck and thorax is essential for precise surgical planning, as well as for averting future potential complications.

References

1. Murray A, Meguid EA. Anatomical variation in the branching pattern of the AA: a literature review. Ir J Med Sci. 2023;192(4):1807-17.
2. Kodikara I, Gamage D, De Soyza S, Ilayperuma I. Computed Tomographic Analysis of AA Branching Patterns: Revisited. SN CompreClin Med. 2022;4(1):17.
3. Popieluszko P, Henry BM, Sanna B, Hsieh WC. A systematic review and meta-analysis of variations in branching patterns of the adult aortic arch. J Vasc Surg. 2018;68(1):298-306.
4. Patil ST, Meshram MM, Kamdi NY, Kasote AP. Study on branching pattern of AA in Indian. Anat Cell Biology. 2012;45(3):203.
5. Pandalai U, Pillay M, Moorthy S, Sukumaran TT. Anatomical variations of the Aortic Arch: a Computerized Tomography-based study. Cureus. 2021;13(2).
6. Aboulhoda BE, Ahmed RK, Awad AS. Clinically-relevant morphometric parameters and anatomical variations of the aortic arch branching pattern. Surg RadioAnat. 2019;41:731-44.
7. Mustafa AG, Allouh MZ, Ghaida JH, Al-Omari MM, et al. Branching patterns of the aortic arch: a computed tomography angiography-based study. Surg Radio Anat. 2017;39:235-42.
8. Shinde SV, Bhusari P, Kathe D, Shukla K. Study on the variation of branching pattern of Arch of Aorta in Cadavers of North Maharashtra. Ind J Anat. 2016;5(2):129-33.
9. Karacan A, Türkvatan A, Karacan K. Anatomical variations of aortic archbranching: evaluation with computed tomographic angiography. CardiolYoung. 2014;24(3):485-93.
10. Singh V. Textbook of clinical embryology, -E-Book. Elsevier Health Sciences. 2022.