

# VARIATIONS OF BRANCHES OF AORTIC ARCH IN NORTH INDIAN POPULATION: A COMPUTED TOMOGRAPHIC STUDY

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## ABSTRACT

**Background:** The major branches of arch of aorta are the great ways for blood supply to the head and upper limb. The aim of this study was to observe the variations in branching pattern of aortic arch and correlate it embryologically and clinically.

**Materials and methods:** Computed tomographic images of aortic arch region from 110 patients were studied retrospectively. Out of 110 patients, 62 were male and 48 female and were of 3 month to 75 years age. The images were reviewed for normal and variant anatomy of aortic arch and the results were analyzed statistically.

**Results:** Normal branching pattern of AA was observed in 61.81% (n=68) of cases. In 27.27% (n=30) cases a common trunk originated from the aortic arch that gave rise to brachiocephalic trunk and left common carotid artery and second branch was left subclavian artery. In 10.89% subjects (n=12) left vertebral artery (LVA) was an additional branch apart from three normal branches of AA. LVA had different mode of origin in these cases.

**Conclusion:** A variant of origin and course of a great vessel arising from the aortic arch is of great clinical value, because lack of knowledge of these variations may lead to serious surgical complications while doing procedures in the superior mediastinum and root of neck.

**KEY WORDS:** Aortic arch, Computed Tomography, Vascular anatomy, Variation

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## INTRODUCTION

Aortic arch is the continuation of ascending aorta, its origin, slightly to the right, is at the level of upper border of the second right sternocostal joint. The arch first ascends diagonally back and to the left over the anterior surface of trachea then back across its left side then finally descends to the left of the fourth thoracic

vertebral body, continuing as descending thoracic aorta. The most common branching pattern of the aortic arch (AA) in humans comprises of three great vessels; first, the brachiocephalic trunk (BCT) then the left common carotid artery (LCA) and finally the left subclavian artery (LSA). This pattern occurs in 65-80% of cases [1].

Variations of aortic arch are common. The incidence of variation of the aortic arch branches in different races ranged from 5% to 35% [2]. There are several ways to study different variations of aortic arch including MRI, echocardiography and angiography using catheter [3]. Each of the methods carries their own problems: MRI has limited use in several vascular diseases and also non-cooperation of the patients with this technique, Echocardiography has limitations in detecting some diseases including abnormality of big arteries and Digital angiography method is invasive and expensive [4]. T-angiography especially CT with 64-rows detector is another method used in detecting aorta arch variations. Its non-invasive and inexpensive nature as well as its requiring less time in comparison with other detective techniques can be referred to as its advantages [5]. Taking a three dimensional image from all angles of a unit vascular complex is possible in this method [6]. Knowledge of variations in the branching pattern of the aortic arch is of great importance for patients who have to undergo four vessel angiography, aortic instrumentation, or supra aortic thoracic, head and neck surgery [7]. In the present study we will observe the variations in branching pattern of aortic arch in North Indian population and correlate it embryologically and clinically and also with gender.

## MATERIALS AND METHODS

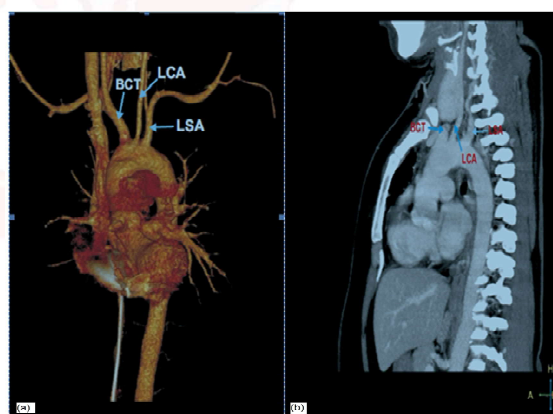
The study was conducted in Department of Anatomy and Department of Radiodiagnosis, King George's Medical University, UP, Lucknow. The study included 110 patients, out of which 62 were males and 48 females. Age of subjects ranged from 3 months to 75 years across 5 age groups. Efforts were made to include sufficient number of subjects from each age group. Written informed consent from the patients was obtained. The images of patients with previous history of allergy to contrast agent, renal insufficiency, distortion of anatomy of arch of aorta due to any pathology were excluded from this study. CT Angiography was performed on 64-slice multidetector spiral CT scanner. A single unenhanced low-dose scan was first obtained. After that 350 mg/ml non-ionic contrast medium (Omnipaque) is injected in the antecubital vein

at the rate of 5.5 ml/sec. A region of interest was drawn on the aorta at the level of the diaphragm. After an appropriate delay to allow passage of the contrast agent into the renal circulation, a series of thin cuts (0.9mm) were obtained throughout the region of aorta. All the images were analysed using Philips DICOM viewer. Number of branches of arch of aorta were indentified in axial, multiplanar reconstructions (MPR) images, and in volume rendered images.

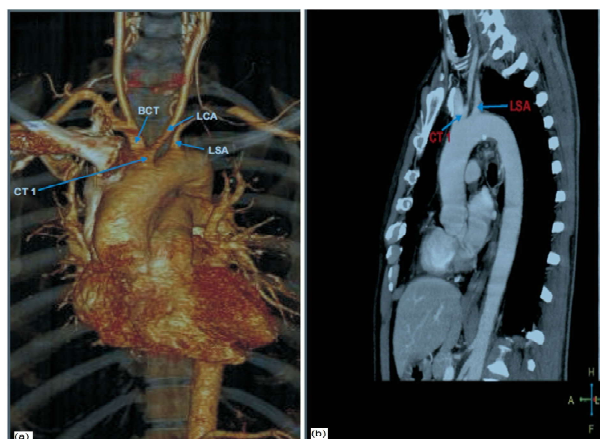
## RESULTS

In the study, normal branching pattern of aortic arch was observed in 61.81% (n=68) cases (Fig. 1). In 27.27% (n=30) cases a common trunk originated from aortic arch, that gave rise BCT and LCA and the second branch was LSA (Fig. 2). In 10.89% subjects (n=12) LVA was arising from arch of aorta as an additional branch apart from three normal branches. LVA had different mode of origin in these cases. In four cases

**Fig. 1:** Showing normal branching pattern of arch of aorta in (a) VR 3D image (b) parasagittal MPR image.



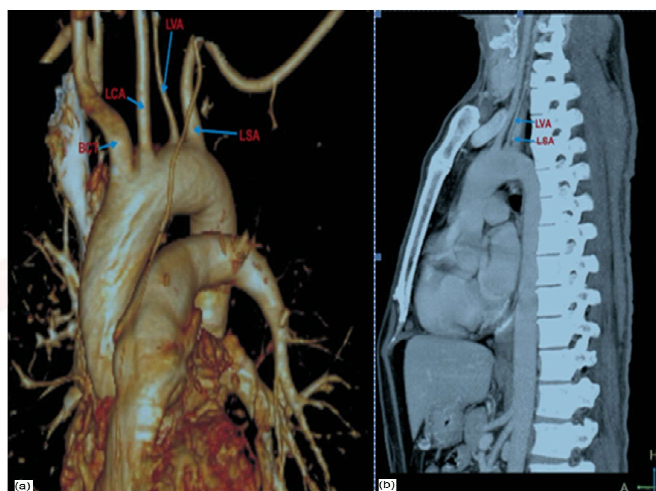
**Fig. 2:** Showing common trunk (CT1) for brachiocephalic trunk (BCT) and left common carotid artery (LCA) in (a) volume rendered 3D image (b) parasagittal MPR image.



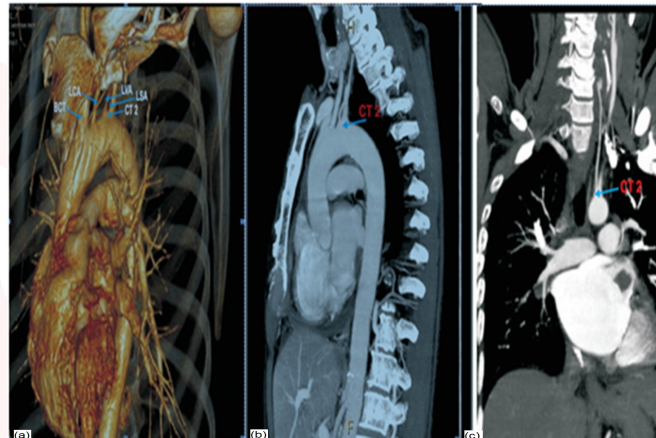
(3.63%) left vertebral artery had separate origin from arch of aorta just proximal to left subclavian artery, thus aortic arch had four branches in sequence- BCT, LCA, LVA, LSA (Fig. 3). Further in four cases (3.63%) left vertebral artery and left subclavian artery shared a common trunk thus branching pattern was BCT, LCA, CT2 (LVA and LSA) (Fig. 4). and in remaining four cases (3.63%) two common trunk arose from arch of aorta, first trunk (CT1) gave rise to BCT and LCA

while second trunk (CT2) divided into left vertebral artery and left subclavian artery (Fig. 5). Normal branching was the most common pattern in both genders. Next common pattern was the one in which two branches were arising from the aortic arch; a common trunk for brachiocephalic and left common carotid arteries and a left subclavian artery. Statistically, there was no significant association between branching pattern and gender.

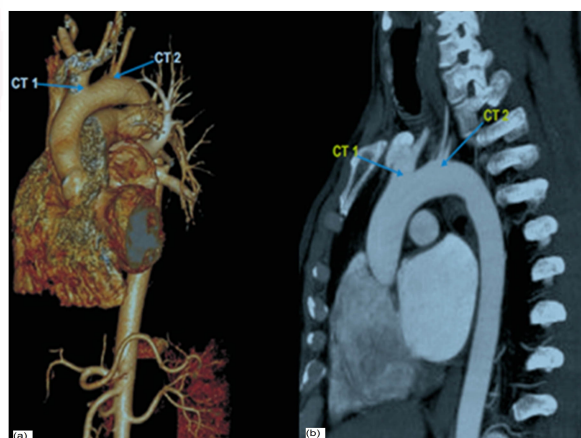
**Fig. 3:** Showing left vertebral artery (LVA) arising directly from the aorta proximal to the left subclavian artery (LSA) in (a) volume rendered 3D & (b) parasagittal MPR image.



**Fig. 4:** Showing left vertebral artery (LVA) shared a common trunk with left subclavian artery (LSA) in (a) VR-3D (b) parasagittal MPR image (c) coronal MPR image.



**Fig. 5:** Showing two common trunk CT1 (common trunk for BCT & LCA) and CT2 (common trunk for LVA and LSA) in (a) volume rendered 3D image (b) parasagittal MPR.



## DISCUSSION

Arterial derangements within the thorax are common, complex and can assume many diverse forms. These derangements in origin and course of main vessels occurring either individually or in combination with other cardiovascular defects are mostly explainable on ontogenic basis, which can be blamed for a myriad of clinically relevant anomalies [8].

In the present study, normal branching pattern of aortic arch was observed in 61.81% cases. Variant branching pattern was observed in 38.19% cases, which is higher than that reported in previous studies (Table 2).

The most common variation in branching pattern that was observed was one in which only two branches were arising from aortic arch out of which one was a common trunk (CT1) that gave rise BCT and LCA and other was LSA. This variation has been documented in various studies (Table 2) but in most of them prevalence is quite less as compared to present study (27.27%). Although Makhanya et al in South African population and Ogeng'o et al in Kenyan population have reported the prevalence of 28.3% and 25.7% which is comparable to present

study [9,10]. The left horn of aortic sac normally forms part of the arch that intervenes between the origins of BCT and LCA. If aortic sac fails to bifurcate into right and left limbs, then LCA will connect to aortic sac directly. This results in a common origin of BCT and LCA. The proximal part of the third aortic arch normally gets extended and absorbed into the left horn of aortic sac.

If it gets absorbed into the right horn of the aortic sac, it results in to variable branching pattern of BCT [11]. Inadvertent occlusion of this common trunk may have major ischaemic complications as it supplies both carotids, the right vertebral and subclavian arteries [12]. Further, this variation is associated with cardiac and coronary arterial abnormalities [13].

Next branching pattern observed in present study was in which apart from three normal branches left vertebral artery was also arising directly from arch of aorta, instead of originating from first part of subclavian artery. We reported this variation in 10.89% cases (n=12). Out of these in four cases (3.63%) LVA was originating directly from AA between LCA and LSA. Incidence of this variation ranged from 1.7-8% in various populations (Table 2).

**Table 1:** Branching Pattern and its distribution in males and females.

Variable	Normal		CT1, LSA		BCT, LCA, CT2		BCT, LCA, LVA, LSA		CT1, CT2		Significance of difference
	No.	%	No.	%	No.	%	No.	%	No.	%	
Overall	68	61.8	30	27.3	4	3.6	4	3.6	4	3.6	$\chi^2 = 0.183$ (df=4); p=0.996
Gender											
Female	30	62.5	12	25	2	4.2	2	4.2	2	4.2	
Male	38	61.3	18	29	2	3.2	2	3.2	2	3.2	

**Table 2:** Frequency of distribution of branching pattern of aortic arch among various Populations.

Author (year)	Population	Type of study	Variant branching pattern (%)	Aortic arch with Two branches (%)	Vertebral artery arising directly from aortic arch (%)
Nelson and Sparks (2001) [14]	Japanese	cadaveric	5.7	1	4.1
Ogeng'o et al (2010) [9]	Kenyan	cadaveric	32.7	25.7	3.53
Makhanya et al (2004) [10]	South African	Conventional angiographic	30	28.3	1.7
Natsis et al. (2009) [7]	Greek	Conventional angiographic	17	1.5	0.79
Muller, et al (2011) [18]	German	64-slice CTA	13.3	8	4.2
Piyavisetpat et al (2011) [2]	Thai	64-slice CTA	11.6	5.97	4.08
Shakeri et al (2013) [15]	Pakistan	64-slice CTA	31.2	11.9	4.2
Rekha, P. and Senthilkumar, S (2013) [19]	South Indian	cadaveric	7.28	4.5	2.72
Current study	North Indian	64-slice CTA	38.19	27.27	10.89

Nelson and Sparks in Japanese population, Shakeri et al in Pakistani population have observed 4% prevalence which is in consensus with present study [14,15].

Further in four cases (3.63%) LVA and LSA shared a common trunk. Similar type of variation was also reported by Alsaif & Ramadan and Nelson and Sparks. Alsaif & Ramadan reported similar prevalence of this variation as observed in present study but Nelson and Sparks found this variation in only 0.54% cases [16,14]. In remaining four cases (3.63%) two common trunk arose from arch of aorta, first trunk gave rise to BCT and LCA while second divided into LVA and LSA. Similar variation was observed by Makhanya et al and Suzuki et al but the prevalence was 1.7% and 0.5% respectively [10,17]. Direct origin of the left vertebral artery from the upper convex surface of the arch of aorta between the origins of the left common carotid and left subclavian arteries may be explained as increased absorption of embryonic tissue of left subclavian artery between the origin of the arch of aorta and the vertebral artery. Knowledge of variations in origin of vertebral artery is important during angiography, thoracic, head and neck surgery [12].

## CONCLUSION

Our data provide information regarding prevalence of variations in aortic arch branching pattern in North Indian population. Cardiovascular, thorax and neck surgeons as well as radiologists and anatomists should be familiar with these variations. Variations in branching pattern of the aortic arch are important during supraaortic angiography or aortic instrumentation and may cause misinterpretation of radiological examination and complications during thoracic and neck surgery.

## ABBREVIATIONS

**CTA** - Computed tomography Angiography

**AA** - Aortic arch

**BCT** - Brachiocephalic Trunk

**LCA** - Left Common Carotid artery

**LSA** - Left subclavian artery

**LVA** - Left vertebral artery

**MIP** - Maximum Intensity Projection

**MPR** - Multiplanar Reconstruction

**CT1** - Common trunk for BCT and LCA

**CT2** - Common trunk for LVA and LSA

**VRT** - Volume Rendered Technique

**Conflicts of Interests: None**

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