

A cadaveric study of aortic arch variations and its embryological basis

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Abstract

Background- Aortic arch variations are usually asymptomatic and are identified incidentally in radiological imaging and in autopsy finding. The aim of this study is to observe the incidence of variation in the branching pattern of arch of aorta in cadavers of Indian origin. **Materials and Methods:** A total of 45 cadavers were included in the study. Arch of aorta and its branches were dissected and noted. Origin of Brachiocephalic trunk, Left common carotid artery and left subclavian artery were noted. **Results:** Type I-Normal three branching pattern was observed in 82.3%. Type II with two branches was seen in 17.7% specimens. In this variant a common trunk giving rise to brachiocephalic trunk (BCT) and left common carotid artery (LCCA) and a separate origin of left subclavian artery to the left of common trunk was seen. A single heart with posterior and left origin of BCT was noted. **Conclusion:** Variation of aortic arch branching is of radiological and surgical significance, particularly in the diagnosis and treatment of head, neck, and chest diseases. Awareness of these variations is particularly relevant for interventionalists who access these vessels during endovascular surgery.

Keywords: Aortic arch, Brachiocephalic trunk, Left Common Carotid artery.

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Introduction

With the advent of endovascular aortic stenting and catheterization of aortic arch for cardiovascular disorders. Studies are being done to understand the normal and variant anatomy of Aortic Arch (AA) branching pattern and its clinical significance. Aortic arch (AA) and its branches supplies the area of head, neck, upper limb and thoracic regions. Normally, it gives three main branches from the upper convex margin of the arch from right to left-Brachiocephalic trunk (BCT), left common carotid artery (LCCA) and left subclavian artery (LSA). The brachiocephalic trunk later divides into right common carotid artery and right subclavian artery. [1,2,3] The flow of blood in these branches is dependent on their level of origin and luminal diameter. Blood flow to these regions is altered based on the variations in their origin and branching pattern. [4] Although the occurrence of variations of aortic branch are rare, lack of awareness of AA variations may lead to clinical misdiagnoses of radiological findings leading to increased incidence of life threatening surgical complications. [5] Though a number of cadaveric and radiological studies have been done with varying incidences. Incidence of variations of aortic arch depends on the population, ethnicity, sex and race [6]. Therefore, this study was undertaken to see the cadaveric variations of aortic arch branching in the department of anatomy in our institute.

Materials and Methods

The study was conducted in the Department of anatomy. Specimens were collected over a period of over a period of 3 years. 45

Cadaveric hearts of both male and female aged between 50-70 years of Andhra Pradesh population were included in the study. Mediastinum was dissected, both lungs were removed and intact heart with aortic arch branches were identified. Origin and Branching pattern of Aortic arch was observed in all specimens. Heart with aortic arch and its branches about 2-5 cms attached with the arch was removed and preserved in 10% formalin. Based on Adachi's classification of branching pattern of AA -Type I, Type II and Type III. The number of specimens of each type was counted and percentage was calculated. Photographs of each specimen were taken and documented.

Results

In the current study, based on Adachi's classification [3], Type I-Normal aortic arch branching with three major branches - brachiocephalic trunk, left common carotid, and left subclavian was seen in 37 (82.3%) out of 45 specimens (Fig 1). Type II branching pattern was noted in 08 specimens (17.7%) in which 2 major branches namely a common trunk and left subclavian artery originated from the aortic arch. The common trunk branched into brachiocephalic and left common carotid artery. (Fig. 2A,B,C). Type III was not observed in any specimen.

Based on the point of origin and course of BCT, in all specimens BCT was to the right of mid-vertebral line, but in one specimen the point of origin was from the posterior surface of arch of aorta and to the left of mid-vertebral line as shown in (Fig 3A,B).

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Fig 1: Showing Normal three branching pattern of Aortic Arch A-Brachiocephalic trunk, B-Left Common Carotid artery, C-Left subclavian artery

Table 1: Comparison of Incidence of type II Arch pattern among other Indian authors studies

Authors	No of Cadavers Studied	Percentage (%)
Budhiraja et al [7]	52	19.2
Patil et al [8]	75	14.66
Nayak SR et al [9]	62	4.8
Present study	45	17.7

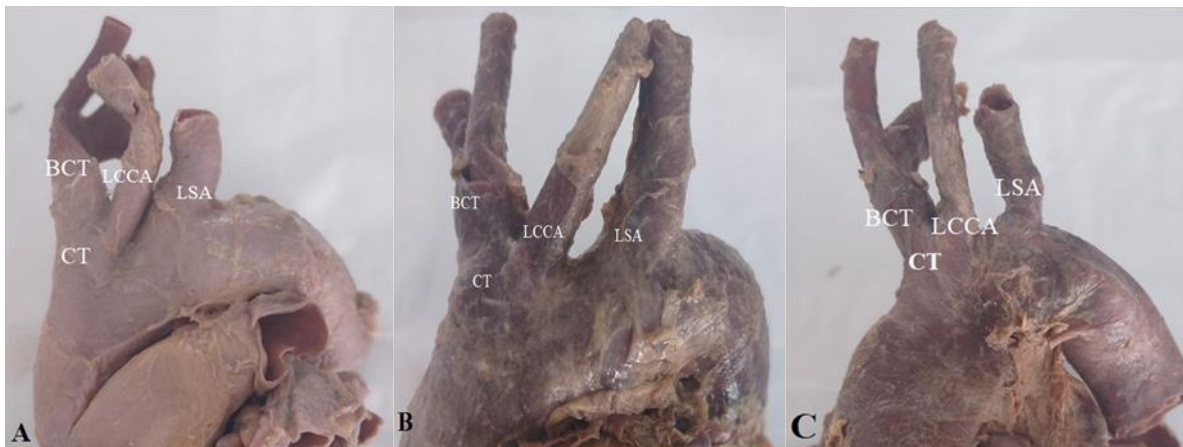


Fig 2 A, B, C:Showing Type II pattern , CT-Common trunk,BCT-Brachiocephalic trunk,LCCA-left Common carotid artery,LSA-left subclavian artery

Discussion

Embryogenesis of Arch of Aorta

Development of Arch of aorta is composite in nature. In early embryogenesis between week 3-4, ventrally placed aortic sac divides into right and left horn sac. From each sac, six pairs of arches are formed connecting the ventrally placed aortic sac to the dorsally placed dorsal aorta. During 4-6 weeks, each arch gives branches that supplies areas of head, neck, upper limb and thoracic region. In the next two weeks, under the influence of growth factors these six arch arteries undergoes transformation into adult pattern. Among the six arches, fifth arch disappears, remaining five arches forms definitive arteries. Arch of aorta develops from left fourth arch artery. Anatomically arch of aorta is a continuation of ascending aorta from right to left, ventral to dorsal and with upward convexity. Hence, the complete arch of aorta develops from three sources from right to left. First part of aortic arch between BCT and Left CCA is formed by left horn of aortic sac, between Left CCA and LSA is derived from left fourth arch artery and distal to left subclavian artery is formed by left dorsal aorta.

According to Study reports of Adachi, three branching pattern that is Type I/A is observed in 80% of individuals. Type II/B Bovine arch variant is seen in 11%. In this variant only a common trunk and left subclavian artery is seen to arise from aortic arch. In type III/C pattern four branches are observed with left vertebral artery directly originating from arch medial to LSA. In the current study, the incidence of normal three branching pattern of AA (BCT, LCCA, LSA) was 82.3%. This incidence of normal branchings within the range of 67-93% as reported by previous cadaveric studies of Indian origin. [7,8,9]. The variant branching pattern observed in our study was the two-branch pattern. This is the most common AA variation observed till date. In this variant, two branches sprouts from arch of aorta – a Common trunk and Left subclavian artery. Common trunk bifurcates into brachiocephalic trunk and Left CCA. The results of the previous cadaveric studies describing two-branch pattern in different population of Indian origin varies from 4% to 19% as summarized in Table 1 [7,8,9]. Various authors have hypothesised aortic arch variation to its embryogenesis. AA variation may result from incomplete bifurcation of the aortic sac into the right

and left sacs.[10].Growth factors like VEGF and TGF-B play a role in the fusion of aortic arch branches and in transformation to adult vessels.Alterations in these growth affects the formation of arch of aorta and its branches.Evidences also suggest that Type II variant has been associated with congenital syndromes such as Trisomy and DiGeorge syndrome.[5,6]Embryologically, in normal three branching pattern right horn of aortic sac forms brachiocephalic trunk and left horn aortic sac forms the first part of arch of aorta between the origin of BCT and LCCA.With the descent of heart and elongation of neck,proximal part of the left third arch artery gets extended and absorbed into the left horn of aortic sac resulting in formation of left CCA.Type II aortic arch variation is due to absorption of left third arch into right horn of aortic sac,resulting in common origin of BCT and LCCA.[11,12,13] Radio-imaging studies in this type of variation have shown significant alteration in the flow of blood to BCT and LCCA, cerebral hemodynamic changes are noted on the left

side when compared to the right.[5]Surgically,this type of variation must be identified before stenting and aortic arch interventions.The choice of the type, size and shape of the cerebral angiographic catheter essentially depends upon the origin and course of AA and its branches.[14]In the current study left CCA originated from CT and crossed obliquely across the trachea from right to left as shown in Fig 2B.Due to this oblique course of LCCA in front of trachea, compression of trachea and injury of LCCA is most likely to happen during tracheostomy.Stenting of LCCA becomes more complicated due to its common origin and oblique course.The findings of the present study is similar to the findings reported by Nayak et al.[9].Hence,awareness of variation of AA and its branches is a prerequisite for angiographic catheter selection and for stenting procedure.[14]

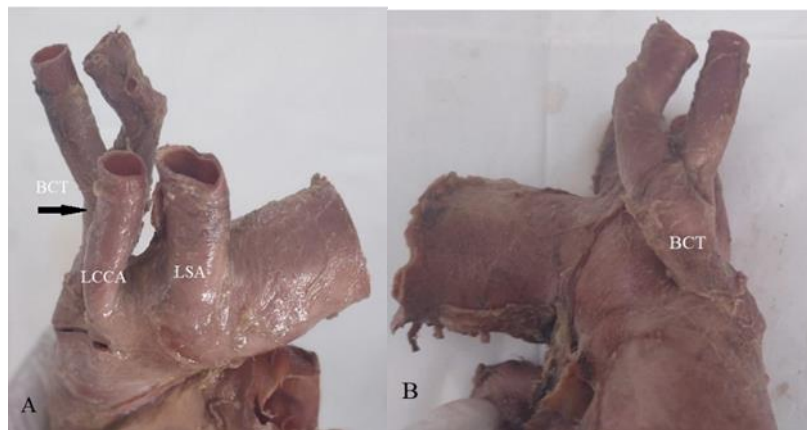


Fig 3: A -Anterior view,B-Lateral view: Showing posterior and left origin of BCT

In the present study another important finding was observed in one heart as shown in (Fig 3A,B). In this heart,the origin of BCT was from the posterior surface of aortic arch and to the left of mid-vertebral line. In normal anatomy the point of origin of BCT lies to the right of mid-vertebral line and that of LCCA and LSA to the left of mid-vertebral line.Embryologically,this migration of BCT from right to left and posterior is due to alteration in the formation of right aortic sac and defect in the fusion of right third aortic arch with the right sac.[15]Skandalakis JE has stated that the point of origin of BCT to the left of the MVP is clinically significant.[16]This abnormal origin of the BCT can lead to tracheal compression and change in blood flow to BCT.Identification of origin and course of BCT is essential prior to any catheterisation of arch of aorta and BCT. Surgical correction of origin and course of BCT is warranted in cases with altered blood dynamics.[17,18]

Conclusion

The findings of the present study in Indian origin cadavers may provide additional information on the branching pattern of arch of aorta. An in-depth knowledge of these variants is paramount to radiologists and surgeons for thoracic and neuroradiological procedures.

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