International Journal of Research in Medical Sciences
Krishnan VKV et al. Int J Res Med Sci. 2019 Apr;7(4):1313-1318
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20191345

Original Research Article

Imaging spectrum and prevalence of variant branching pattern of aortic arch

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Received: 07 February 2019
Accepted: 07 March 2019

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ABSTRACT

Background: Variant branching patterns of the aortic arch are not infrequent but are commonly under reported. This study was conducted to determine the spectrum of Variant branching pattern of aortic arch and their prevalence using contrast enhanced computed tomography (CECT) images of the cases from a tertiary care centre.
Methods: Contrast enhanced computed tomography (CECT) images of aortic arch region from 1116(629 male and 487 female) cases from 18 to 85 years of age were examined retrospectively. The images were reviewed for normal and variant anatomy of aortic arch and the results were analyzed statistically.
Results: Of 1116 patients, 878 (78.6%) cases showed normal and 238 (21.3%) cases had variant branching pattern of the aortic arch. The most common variation was the common origin of brachiocephalic trunk (BCT) and the left common carotid artery (LCCA) which was observed in 160 (14.3%) cases. In 8 (0.7%) cases, BCT and LCCA took origin from a single common trunk arising from the aortic arch. In 60(5.4%) cases, the left vertebral artery (LVA) originated directly from the aortic arch between the origin of the LCCA and left subclavian artery (SCA). 8 (0.7%) cases had aberrant right subclavian artery. Two (0.2%) cases showed right aortic arch.
Conclusions: Interventional radiologists and surgeons should be well aware of variant anatomy of aortic arch. Contrast CT is a highly reliable imaging method for demonstrating anatomical features and variations of the arch.

Keywords: Aberrant subclavian, Anatomical variants, Aortic arch, Contrast enhanced computed tomography

INTRODUCTION

Ascending aorta continues as arch of aorta in the superior mediastinum. Aortic arch begins slightly to the right and lies at level with the upper border of the right second sternocostal joint. At first, the arch ascends diagonally towards posterior and to the left lying across the anterior aspect of the trachea, and finally descends to the left of the D4 vertebral body and proceeds as the descending thoracic aorta. It ends at the level of sternal end of the second left costal cartilage.[1] There are three major branches arising from the convex surface of the arch. In the standard anatomical configuration, the aortic arch is left sided and its commonest branching model comprises of three great vessels; from right to left first the brachiocephalic trunk (BCT), then the left common carotid artery (LCCA), and finally the left subclavian artery (SCA).[2] The BCT branches into right SCA and right common carotid artery (RCCA). This branching pattern occurs in 65-94% of the cases and they are accounted as "normal".[3-8]

Variant branching pattern of the aortic arch includes the variation in the number of branches and in the origins of different branches from the arch.[6] Most of the anomalies of the arch of aorta and its branches are attributable to altered ontogenesis of primitive aortic arches of the embryo during the early pregnancy period.[9] Awareness of

normal anatomy and frequency of variations in the branching convention of the arch of aorta is of paramount importance in patients being planned for aortic instrumentation, four vessel angiography or any diagnostic, surgical, or interventional procedure of the thorax and neck.

Also, anomalous origins and the distribution of the great vessels can induce alterations in the cerebral hemodynamics that can result in cerebrovascular accidents.[10] The present study was attempted to elucidate the appearance of anatomical variations in branching pattern and positional alterations of the aortic arch and to estimate the prevalence from 1116 patients, who underwent contrast CT studies of the thorax in a tertiary care center over a period of one year.

METHODS

The study was conducted in the Department of Radiodiagnosis, Amala institute of medical sciences, Thrissur, Kerala.

The hospital picture archiving and communication system (PACS) was interrogated to identify all patients who underwent contrast CT examination of the thorax (including CT aortogram and CT pulmonary angiography), for various purposes retrospectively over the period starting from January 1 to December 31, 2018.

All consecutive patients were included irrespective of, and without knowledge of, the indication. The study included 1116 patients, out of which 629 were males and 487 females. Age of subjects ranged from 18 to 85 years.

Image Analysis

The obtained axial images from picture archiving and communication system (PACS) were transferred to the work station (GE medical systems Milwaukee, USA) where the image analysis was performed by an experienced practicing radiologist.

Number of branches of arch of aorta were identified and the branching pattern was analyzed in axial, multiplanar reconstructions (MPR) and post processed (maximum intensity projection and 3D volume rendered) images. Examinations were excluded when clear identification of the arch anatomy was not possible due to technical reasons (e.g., motion artefact), or in cases of prior arch reconstructive surgery.

RESULTS

The prevalence obtained in is summarized in the pie-diagram given (Figure 1).

Normal branching pattern of aortic arch (Figure 2) was observed in 78.6 % (n=878) cases.

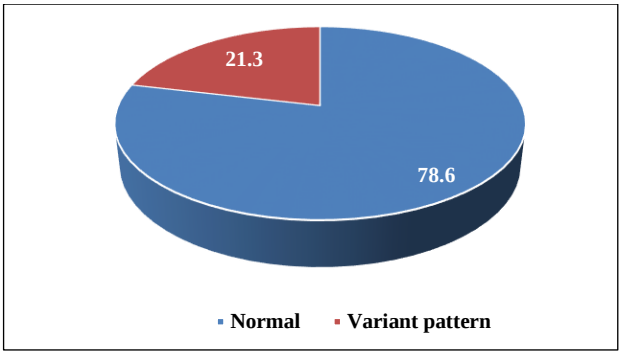

Figure 1: Distribution of various branching patterns of aortic arch.

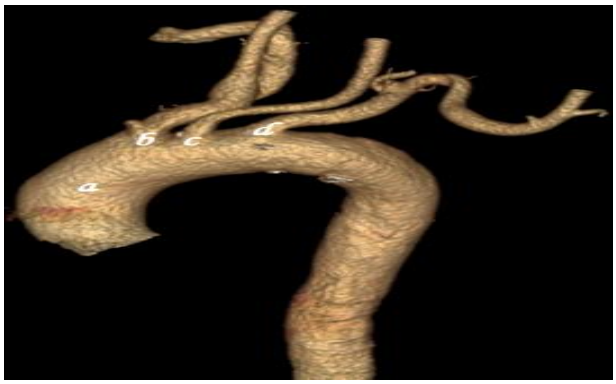

Figure 2: VR image showing normal branching pattern of aortic arch (a-aorta, b-BC c- left common carotid artery (LCCA), d- Left subclavian artery (LSCA)).

In 14.3% (n=160) cases a common origin was shared by both brachiocephalic trunk (BCT) and left common carotid artery (LCCA) (Figure 3).

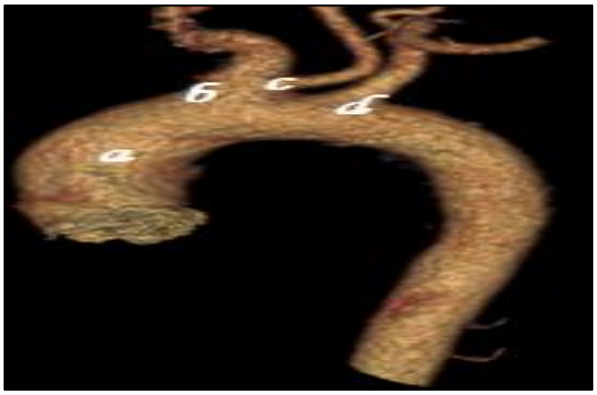

Figure 3: VR showing common origin of brachiocephalic trunk (BCT) and left common carotid artery (LCCA) (a-aorta, b-BCT, c-LCCA, d- Left subclavian artery (LSCA)).

In 8 (0.7%) cases, brachiocephalic trunk (BCT) and left common carotid artery (LCCA) took origin from a single common trunk arising from the aortic arch and the second branch was LSA (Figure 4).

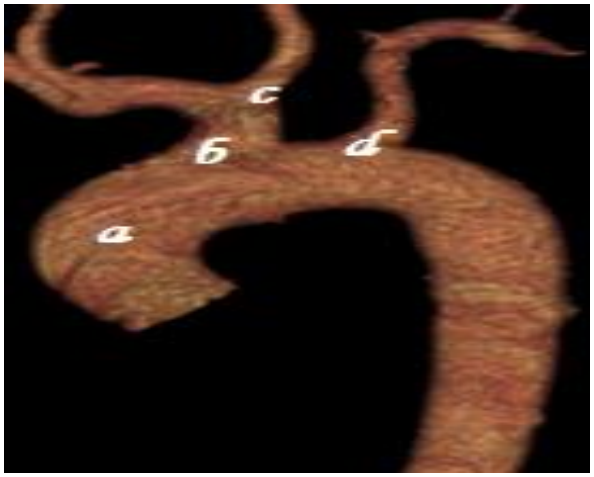

Figure 4: VR image showing brachiocephalic trunk (BCT) and left common carotid artery (LCCA) arising as a single trunk (a-aorta, b-BCT, c-LCCA, d-Left subclavian artery (LSCA)).

In 5.4% cases (n=60) the left vertebral artery (LVA) originated directly from the aortic arch between the origin of the left common carotid artery (LCCA) and left SCA, providing a pattern with four branches (from right to left - brachiocephalic trunk (BCT), LCCA, LVA, and left SCA) (Figure 5).

Figure 5: VR image showing variant origin of Left vertebral artery from aortic arch (a-aorta, b-BCT, c-left common carotid artery (LCCA), d-L Vertebral artery, e- Left subclavian artery (LSCA)).

There were 8 (0.7%) of our cases had aberrant right subclavian artery, left common carotid artery (RCCA, LCCA, left SCA, and right SCA) (Figure 6) of which four of them showed a common truncal origin of both CCAs (Figure7 and Figure 8).

The right SCA was the last branch of the aortic arch coursing to the right behind the esophagus.

Two cases had right aortic arch with aberrant left subclavian artery.

Figure 6: VR image showing aberrant right subclavian artery noted arising from posterior aspect of the arch as its last branch and crossing the midline to reach right side (a-aorta, b- aberrant right subclavian artery).

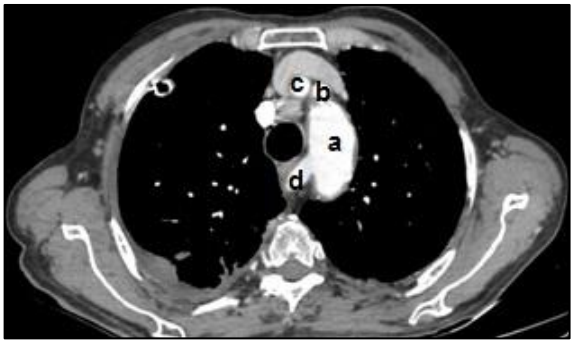

Figure 7: Contrast enhanced computed tomography (CECT)image of aberrant right subclavian artery noted arising from posterior aspect of arch (a-aorta, b-LSCA, c-single trunk for both CCA, d- Aberrant right subclavian artery).

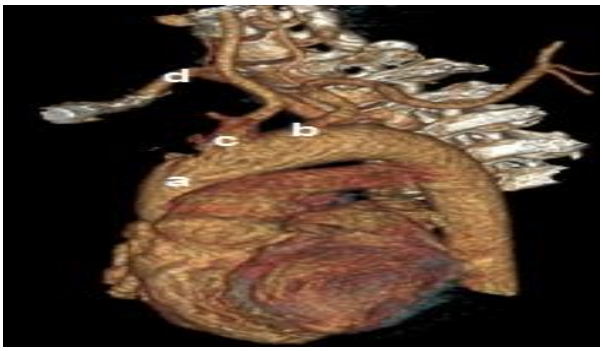

Figure 8: VR image showing aberrant right subclavian artery with both carotid arteries noted originating as a single trunk from the arch (a-aorta, b-Left subclavian artery (LSCA), c-single trunk for both CCA, d- aberrant right subclavian artery).

The vessels originated in the following order from left to right left common carotid artery (LCCA), RCCA, right SCA, and left SCA (Figure 9 and 10).

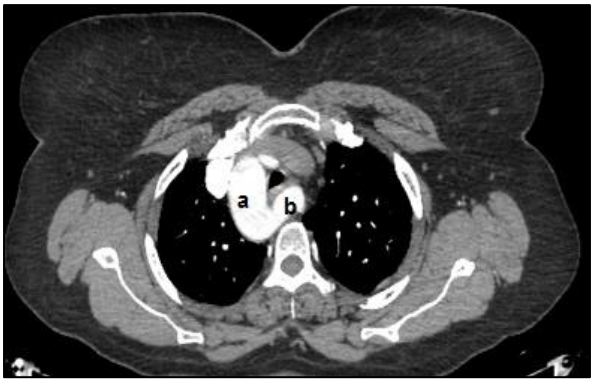

Figure 9: Contrast enhanced computed tomography (CECT) image showing a right sided aortic arch with an Aberrant left subclavian artery noted arising from posterior aspect of the arch as its last branch and crossing the midline (a-aorta, b- aberrant left subclavian artery).

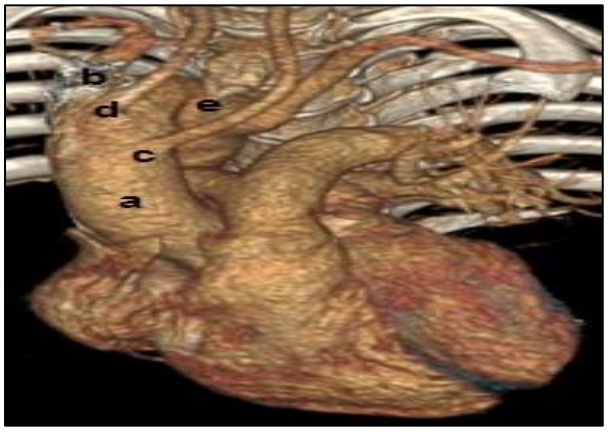

Figure 10: VR image showing a right sided aortic arch seen continuing as descending aorta without crossing to left side with an aberrant left subclavian artery noted arising from posterior aspect of the arch as its last branch and crossing the midline (a-aorta, b- Right subclavian artery (RSCA), c- left common carotid artery (LCCA), d- RCCA, e- aberrant left subclavian artery).

DISCUSSION

There is paucity of imaging based in-depth studies regarding analysis of variant branching pattern of aortic arch, barring a few which are mentioned below. To the best of the authors' knowledge, this is one of the largest contrast CT based study, to date, regarding the variant branching anatomy of aortic arch in a living patient population. The normal three-branch pattern of the aortic arch is encountered with an incidence of 65-94% according to the literature.[3-8] In the present study, such normal pattern was detected in 78.6 % of the cases and the remaining 21.4% cases showed variations from usual branching pattern (Figure 11).

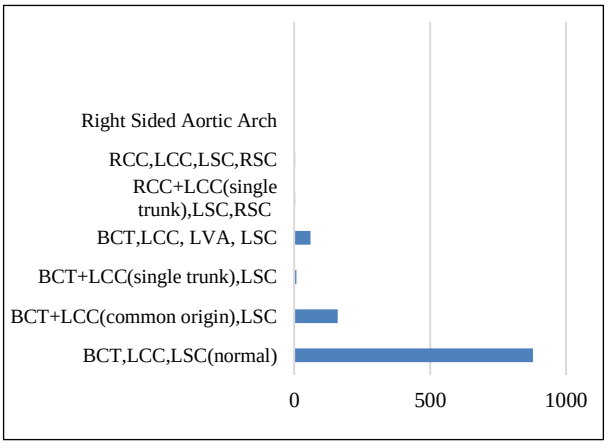

Figure 11: Distribution of various branching patterns of aortic arch.

This finding was similar to the inferences of Lippert H et al and Pabst et al, Shin Y et al, (84%).[11,12] The common origin of both brachiocephalic trunk (BCT) and left common carotid artery (LCCA) with left subclavian artery arising normally from the aortic arch is the most common variation observed with an incidence of 10-22% in the literature.[13-17] Study performed by Jakanani GC et al and Adair W et al, found this variation in 20% of the cases, whereas in 14.3% of cases had such a variation.[5]

This type is also referred as "bovine aortic arch".[18,19] However, it is a misnomer because it does not in fact resemble the aortic arch of the cattle which has got only a single branch that divides into right subclavian artery, a common truncus for common carotid arteries and left subclavian artery.[20]

Also, in 8 (0.7%) of our cases, brachiocephalic trunk (BCT) and left common carotid artery (LCCA) took origin from a single common trunk arising from the aortic arch and the second branch was LSA. Such an origin of BCT and left common carotid artery (LCCA) from a single common trunk is described as Truncus bicaroticus by some authors.[6] Origin of the left vertebral artery from the aortic arch is not unusual and the reported prevalence is between 2.4 and 8%.[21] The commonest location is between the Left CCA and left SCA.[7] At times, the left vertebral artery is the terminal branch of the aortic arch.

In the current study, the left vertebral artery having origin from aortic arch between the LCCA and left SCA was observed in 5.4% of the cases. Bhatia et al, performed an autopsy-based study on a series of 81 cases.[22] Similar to the present results, they found a 7% frequency of aberrant left vertebral artery arising from the arch. Satti SR et al, claim that patients with such anomalies should be screened for coexistent aneurysms.[23] The aberrant right subclavian artery is the last branch of the aortic arch in

about 1% of individuals.[24] Authors observed 8 cases (0.7%) with aberrant right SCA.

Lale et al, observed similar 0.2% occurrence in his study of 881 cases.[25] In their study, aberrant right subclavian artery coursed to the right behind the esophagus in 80% of the cases, between the esophagus and trachea in 15%, and anterior to the trachea or main stem bronchus in 5%.[7] In all the cases of aberrant right SCA in our study, the right subclavian artery (RSCA) passed behind the esophagus.

This can cause dysphagia in some patients owing to its retroesophageal course and is known as "dysphagia lusoria".[3] Other variations of the aortic arch could accompany the right aberrant subclavian artery. The commonest is a single trunk for CCAs which is seen in 20-29% of the right retro esophageal subclavian arteries.[23] In the present study, authors had four cases (50%) of such a common trunk for CCAs.

The commonest type is a right aortic arch with an aberrant left SCA. This type is rarely associated with congenital heart disease.[26] In the current study two cases showed right aortic arch (0.2%) with aberrant left SCA (Table 1).

Table 1: Distribution of various branching patterns of aortic arch.

Branching sequence	No. of cases	Percentage
BCT, LCCA, LSCA (normal)	878	78.6
BCT+LCCA (common origin), LSCA	160	14.3
BCT+LCCA (single trunk), LSCA	8	0.7
BCT, LCCA, LVA, LSCA	60	5.4
RCCA+LCCA (single trunk), LSCA, aberrant RSCA	4	0.3
RCCA, LCCA, LSCA, aberrant RSCA	4	0.3
Right sided aortic arch	2	0.2

BCT-brachiocephalic trunk, LCCA- left common carotid artery, RCCA- Right common carotid, LSCA- Left subclavian artery, RSCA- Right subclavian artery, LVA- left vertebral artery.

Natsis KI et al, investigated the aortic arches of 633 patients who had undergone digital subtraction angiography and determined 8 types of aortic arches.[27] In our study, patients with types I, II, III, V and VII only were present.

CONCLUSION

Variations in the branching rule of aortic arch are not uncommon. Most of them are asymptomatic and generally observed as a concomitant finding in routine diagnostic processes and contrast CT is a reliable tool to assess aortic arch. Head and neck surgeons and interventional radiologists ought to be mindful of aortic arch variations. Identification of these vascular variations prior to diagnostic interventions is critical so as to avert.

ACKNOWLEDGEMENTS

Authors would like to thank Dr. Robert P Ambooken, Professor and HOD and all the faculty members of Dept. of Radio-Diagnosis.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

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Cite this article as: Krishnan VKKV, Narayan V Ibrahim N, Mathew J,James SM. Imaging spectrum and prevalence of variant branching pattern of aortic arch. Int J Res Med Sci 2019;7:1313-8.