A STUDY ON BRANCHING PATTERN OF ARCH OF AORTA AND ITS VARIATIONS

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ABSTRACT

BACKGROUND

Normally, the arch of aorta gives three branches- brachiocephalic trunk, left common carotid and left subclavian arteries. The variations in the branching pattern of aortic arch are numerous due to the altered development of the fourth aortic arch during the embryonic period of gestation. These variations maybe of great surgical importance. Many variations occur in the number and position of vessels arising from the aortic arch. Variations in the branching pattern of aorta are due to the altered development of the fourth aortic arch during the embryonic period of gestation. Aortic arch in human is produced by the persistence and development of the left fourth arch. Usually, the arch of aorta gives three branches, i.e. brachiocephalic trunk, left common carotid and left subclavian arteries. The variations of branching patterns of aortic arch are numerous. Although, many of these variations cause no disturbance in the functions of the body, they may be of great importance to the surgeon.

MATERIALS AND METHODS

50 human cadaveric hearts with intact arch of aortae from the Department of Anatomy, Government T.D. Medical College, Alappuzha, Kerala, were used to study its branching patterns.

RESULTS

The usual branching pattern of aorta into three branches, i.e. brachiocephalic trunk, left common carotid and left subclavian arteries was found in 78%. In 14%, the aortic arch gave rise to two branches, a common trunk (for left common carotid and brachiocephalic trunk) and a left subclavian artery. In 8%, the aortic arch gave rise to four branches, namely brachiocephalic trunk, left common carotid, left vertebral and left subclavian arteries.

CONCLUSION

The arch of aorta maybe of different branching patterns due to developmental variations. A knowledge about the variations of branching patterns of arch of aorta will help the surgeon during cardiothoracic surgeries.

KEYWORDS

Arch of Aorta, Brachiocephalic Trunk, Common Carotid Artery, Subclavian Artery.

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BACKGROUND

Many variations occur in the number and position of vessels arising from the aortic arch. Variations in the branching pattern of aorta are due to the altered development of the fourth aortic arch during the embryonic period of gestation. Aortic arch in human is produced by the persistence and development of the left fourth arch. Usually, the arch of aorta gives three branches, i.e. brachiocephalic trunk, left common carotid and left subclavian arteries. The variations of branching patterns of aortic arch are numerous. Although, many of these variations cause no disturbance in the functions of the body, they may be of great importance to the surgeon.

Aims and Objectives

The materials for the present study comprised of 50 human hearts with intact arch of aortae from cadavers and preserved specimens with no sex or age discrimination, which were used for the routine undergraduate dissection in the Department of Anatomy, Government T.D. Medical College, Alappuzha, to study the proportion of variations in the branching pattern of arch of aorta.

MATERIALS AND METHODS

In all the specimens, which were studied, the arch of the aorta began as a continuation of the ascending aorta behind the right second chondrosternal joint. The branches arose from the convexity of the aortic arch. The usual branching pattern of aorta into three branches, i.e. brachiocephalic trunk, left common carotid and left subclavian arteries were found in 39 cases (78%) of 50 specimens (Table 1).

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Sl. No.	Number of Branches	Description of Branches	Frequency in 50 Cases	%
1.	3	BCT, LCC, LSA	39	78%
2.	2	CT (BCT and LCC), LSA	7	14%
3.	4	BCT, LCC, LSA, LVA	4	8%
4.	Others	Nil	0	0

Table 1. Types and Proportions of Aortic Arch Variations in the Present Study

(BCT- Brachiocephalic Trunk, LCC- Left Common Carotid Artery, LSA- Left Subclavian Artery, CT- Common Trunk, LVA- Left Vertebral Artery).

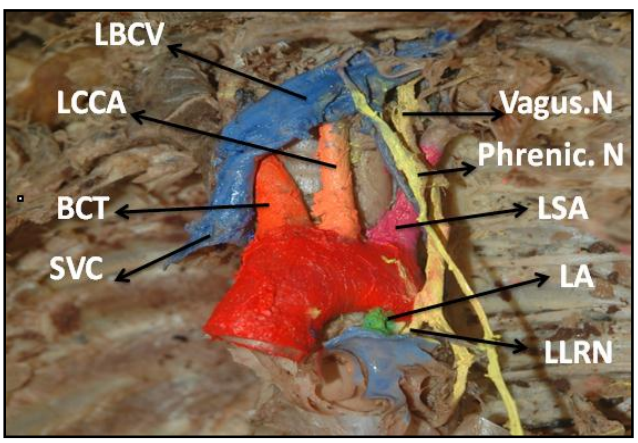

Figure 1. Shows Normal Branching Pattern of Arch of Aorta into Brachiocephalic Trunk (BCT), Left Common Carotid Artery (LCCA) and Left Subclavian Arteries (LSA) and its Relations (LLRN- Left Laryngeal Recurrent Nerve, LA- Ligamentum Arteriosum)

Out of the remaining 11 specimens, there were three different types of variations. In 7 cases (14%), the aortic arch gave rise to two branches (Table 1), i.e. a common trunk (for left common carotid and brachiocephalic trunk) and a left subclavian artery (Figure 2 and Figure 3).

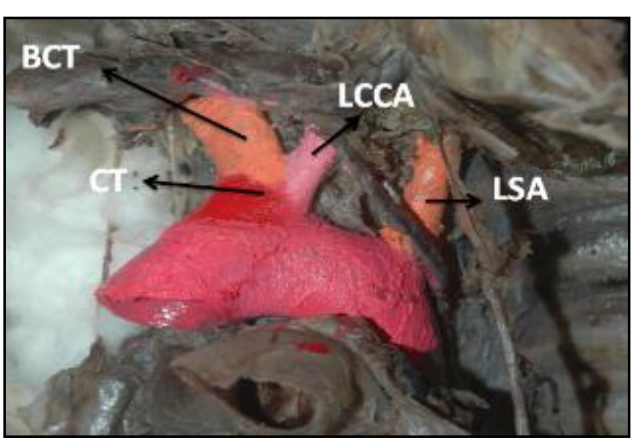

Figure 2. Shows Common Trunk (CT) for Left Common Carotid and Brachiocephalic Trunk

In 6 out of 7 cases (Figure 2) of this type, the common trunk was short and the left common carotid artery started from the root of brachiocephalic trunk (common ostium for BCT and LCCA). In one specimen, the common trunk was long, which then trifurcated into Right Subclavian artery (RSA), Right Common Carotid (RCCA) and Left Common Carotid Arteries (LCCA) (Figure 3).

Figure 3. Shows a Common Trunk (CT), Which Trifurcated into Right Subclavian (RSA), Right Common Carotid (RCCA) and Left Common Carotid (LCCA) Arteries

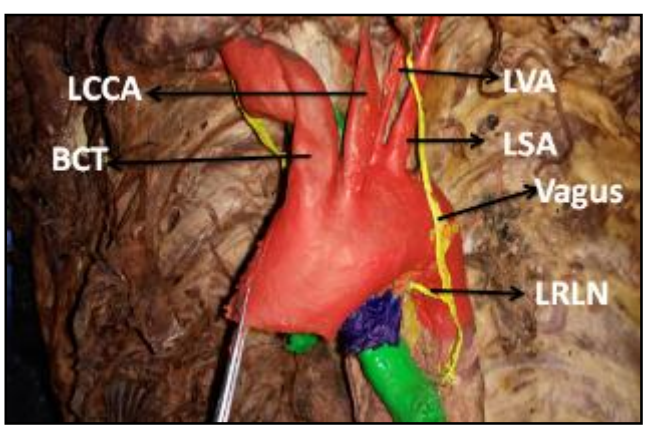

Figure 4. Shows Branching of Arch of Aorta into Brachiocephalic Trunk (BCT), Left Common Carotid Artery (LCCA), Left Vertebral Artery (LVA) and Left Subclavian Arteries (LSA)

In 4 cases (8%), the aortic arch gave rise to four branches namely brachiocephalic trunk, left common carotid, left vertebral and left subclavian arteries (Figure 4).

RESULTS

The variations in the branching patterns of aortic arch are numerous. An analysis of variation in branches from 1000 aortic arches by Anson B. J[1] (1961) showed the usual branching pattern of arch of aorta into three branches, i.e. brachiocephalic trunk, left common carotid and left subclavian arteries in 64.9%; a left common carotid shared the brachiocephalic trunk in 27% and the four large arteries, namely brachiocephalic trunk, left common carotid, left vertebral and left subclavian arteries branched separately from arch of aorta in 2.5%. The remaining 5.5% showed a great variety of patterns, of which the most common (1.2%) being symmetric right and left brachiocephalic trunks. In the present study, we found the usual branching pattern of aorta into three branches in 78% of cases, the left common carotid

shared the brachiocephalic trunk in 14% of cases and in 8% of cases the aortic arch gave rise to four branches, namely brachiocephalic trunk, left common carotid and left vertebral and left subclavian arteries. Other varieties of branching patterns of arch of aorta was not observed in this study.

Development of the aorta takes place during the third week of gestation.[2] There are six pairs of aortic arches that develop between the ventral and dorsal aortae. Arch of aorta develops from 3 sources; i) Left limb of aortic sac (forms part of arch, which extends between the origins of the brachiocephalic trunk and left common carotid artery, ii) Left 4th aortic arch (forms that part of the arch, which extend between left common carotid and left subclavian), iii) Left dorsal aorta forms distal part of arch of aorta, which extends up to 4th thoracic segment. The variations in the branching pattern of arch of aorta can be explained by persistence of segments of the aortic arches that normally regress or disappearance of segments that normally remain or both[3] Momma[4] et al (1999) noted that aortic arch anomalies are associated with chromosome 22q11 deletion.

Author's Name	Total Cases	Branching Patterns of Aorta			
		BCT, LCCA, LSA	CT (BCT, LCCA), LSA	BCT, LCCA, LVA, LSA	Others
Adachi[5] (1928)	516	83.3%	10.9%	4.3%	0.8%
Anson[1] B.J. (1963)	1000	64.9%	27.0%	2.5%	5.5%
Nelson and Sparks[6] (2001)	193	94.3%	1.0%	4.1%	0.6%
Satyapal,[7] et al (2003)	320	94.7%	3.4%	1.6%	0.3%
Nayak[8] SR, et al (2006)	62	91.4%	4.8%	1.6%	2.2%
Shin,[9] et al (2008)	25	84.0%	8.0%	8.0%	0.0%
Ogeng'o,[10] et al (2010)	113	67.3%	25.7%	6.2%	0.8%
Sumit T.P.,[11] et al (2012)	58	77.3%	14.7%	8.0%	0.0%
Federico Meta[12] (2012)	900	81.6%	14.0%	4.4%	0.0%
Pasaoglu Lale[13] (2014)	881	87.4%	7.2%	2.8%	2.6%
Ajith Kumar,[14] et al (2015)	42	83.3%	2.4%	11.9%	3.4%
Current study	50	78.0%	14.0%	8.0%	0.0%

Table 2. Comparison of Branching Patterns of Aorta in Present and Previous Studies

In previous studies, the proportions of the usual branching pattern into three branches was observed between 64.9% and 94.7% (Table-2). In the current study, the usual branching pattern was observed in 78% of cases. This coincides with the studies conducted by Adachi[5] (1928), Shin[9] et al (2008), Sumit T. P.[11] et al (2012), Federico Meta[12] (2012) and Ajith Kumar[14] et al (2015) (Table 2).

DISCUSSION

In the present study, the two branch pattern of aortic arch into a common trunk (for brachiocephalic and left common carotid artery) and a left subclavian artery was observed in 14% of cases. In previous studies, the percentage range was between 11% and 27%. The results observed in the present study are comparable with the studies reported by Federico Meta[12] (2012) and Sumit T.P.[11] et al (2012) (Table 2). Nelson and Sparks[6] (2001), Satyapal[7] et al (2003) and Nayak S R[8] et al (2006) reported a low incidence of two branched pattern into a common trunk and a left subclavian artery. This type of arch of aorta with common trunk and a left subclavian artery is widely considered as Bovine aortic arch, but it doesn't have resemblance to bovine arch. In cattle, a single great vessel arises from the arch of aorta, which gives rise to both subclavian arteries and a bicarotid trunk. The bicarotid trunk then bifurcates into right and left common carotid artery. In the current study, 6 out of 7 cases (Figure 2) with common trunk, the trunk was short and the left common carotid artery started from the root of brachiocephalic trunk. This can be considered as common ostium for BCT and LCCA, which was described by Julio Arturo Huapaya[15] et al in their study on aortic arches in Peruvian population (2015).

Developmentally, the two-branch pattern of the arch of aorta maybe explained as follows- aortic sac usually bifurcates into right and left limbs. Left limb of the aortic sac forms the part of arch that intervenes between the origins of BCT and LCCA. If the proximal part of the left 3rd arch gets absorbed into the right horn of the aortic sac, then BCT and LCCA will have a common trunk. If the absorption takes place proximally, then it results in the formation of common ostium for Brachiocephalic Trunk (BCT) and Left Common Carotid Artery (LCCA). If the absorption takes place distally, then the length of the common trunk will be more.

Sprouting of the left vertebral artery from the aortic arch is not rare and the reported prevalence is between 2.4 and 8%. In the present study also, we found 8% of cases with left vertebral artery arising directly from the arch of aorta. The most frequent location is between the left common carotid artery and left subclavian artery.[2] Sometimes, the left vertebral artery arises as the last branch of the arch of aorta. A case with anomalous origin of both vertebral arteries as additional branches of the arch of aorta distal to the left subclavian artery has been reported.[16] Best and Bumpers[17] (2012) reported a case in which the right vertebral artery originated directly from the aortic arch. In the current study, in all of the 4 cases of direct origin of left vertebral artery from the arch of aorta was seen to sprout between the LCCA and left subclavian artery. Embryologically, the first part of LVA develops from proximal part of dorsal branch of seventh cervical segmental artery proximal to postcostal anastomosis. The second part is derived from longitudinal communications of the postcostal anastomosis. Sprouting of the left vertebral artery from the aortic arch maybe due to the persistence of the left sixth segmental artery as the first

part of vertebral artery and the failure of a segment of dorsal aorta to disappear. It may also be due to the increased absorption of embryonic tissue of LSA between origins from the aortic arch to the origin of vertebral artery resulting in direct origin of the LVA from aortic arch. According to Bernardi and Detori,[18] (1975) the unusual origin of the vertebral artery may cause alterations in the cerebral haemodynamics. If the vertebrobasilar axis is dominant and communication at the arterial circle of Willis is poor, such anomalies can cause ischaemia as well as infarction of the brain stem and cerebellum. According to Satti[19] et al, aneurysms may coexist in patients with unusual origin of vertebral artery and such patients should be screened for aneurysms.

One of the rare variations in the branching pattern of arch of aorta is the origin of the right subclavian artery as the last branch of the arch of aorta,[20] which is seen in approximately 1% of individuals. Right subclavian artery usually courses to the right behind the oesophagus, sometimes between the oesophagus and trachea and rarely passes anterior to the trachea or main stem bronchus. This variation, which is also called "arteria lusoria" is one of the most common vascular ring variations of the arch of aorta. Retroesophageal course may cause dysphagia. No such variations was observed in the present study. The possible embryological basis of anomalous origin of the right subclavian artery is the early involution of the right fourth aortic arch and the cranial part of the right dorsal aorta. Consequently, the right subclavian artery develops from the right seventh dorsal intersegmental artery and from the distal segment of the right dorsal aorta. As development continues and the arch of aorta forms a differential growth shifts the origin of the right subclavian artery closer to the left subclavian artery.

A bi-innominate sequence in which paired vessels are the only derivatives of the aortic arch is found in 1.2% by Anson[1] et al (1961) and 1.6% by Soubhagya R. Nayak,[8] et al (2006). The abnormal left brachiocephalic trunk was formed by the fusion of the proximal part of the left third arch artery and left seventh intersegmental artery into the left fourth arch artery, which was responsible for the left subclavian artery and the left common carotid artery arising from a common trunk, but this variation was absent in the present study.

Uncommonly, the external carotid,[21] internal carotid,[22] thymic[23] and thyroidea ima[24] have been found arising directly from the aortic arch. These rare variations were also not observed in the current study.

CONCLUSION

The present study was conducted in 50 human cadaveric arches of aortae to analyse its branching patterns. The usual branching pattern of aorta into three branches, i.e. brachiocephalic trunk, left common carotid and left subclavian arteries was seen in 78%. In 14%, the aortic arch gave rise to two branches, a common trunk for left common carotid and brachiocephalic trunk and a left subclavian artery. In 8%, it was seen that the aortic arch gave rise to four branches namely brachiocephalic trunk, left common carotid, left vertebral and left subclavian arteries. These variations have a strong embryological basis. The knowledge of variations in the branches of arch of aorta is helpful during cardiothoracic surgeries.

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