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Research Paper Anatomy

Study of the Normal and Variant Branching Pattern of the Aortic Arch: the Clinical and Embryological Significance

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ABSTRACT

A knowledge of the branching pattern of the arch of aorta is of great importance today as the arch is assuming a key role in many endovascular surgeries. The varying branching pattern of the arch, a result of the complicated development, is one of the main risk predictors in endovascular surgeries such as carotid artery stenting.

The present study,for the branching pattern of the aortic arch has been done on 35 embalmed human cadavers, at MGM Medical College, Navi Mumbai

The arch showed variant branching pattern in 11.43% cadavers. In variations, the arch was found to give rise to only 2 branches in 3(8.58%) cadavers and 4 branches in 1(2.58%) cadaver as against normal pattern of 3 branches.

The arch morphology is variable and becomes more so with the advancing age. In this era of increasing vascular invasive procedures the knowledge thus gained will be useful to the cardiologists, cardiothoracic surgeons and radiologists in various diagnostic and therapeutic procedures.

KEYWORDS : Aortic arch, Branching pattern , Vertebral artery

INTRODUCTION

The configuration of the arch of aorta and its branching pattern is assuming a key role in many endovascular surgeries, like carotid artery stenting, due to their role as one of the main risk predictors.

The varying configuration of the arch and its branches is a result of their complicated development from the right and left horns of the aortic sac and first five branchial arch arteries.

Clinically oriented anatomy (2010, p. 174) states, clinically significant variations occur in almost 35 % of the population.

The arch normally gives origin to three branches. .Some of the variant branching patterns of the arch may pose surgical problems.

As per Ughade JM, Kardile PB, Ughade MN, Chaware PN, Pandit SV (2012), left vertebral artery when arises as a variation directly from the arch (up to 5%) poses a problem in preoperative diagnosis with available radiological techniques, due to its smaller size which gets overshadowed by the other larger branches of the arch.

Studying branches of the arch with respect to their variations helps in understanding the cerebral hemodynamics and the cerebral abnormalities. (Shivkumar GL, Pamidi N, Somayaji SN, NayakS,Vollala VR, 2010)

MATERIAL AND METHOD

The study has been conducted in the department of Anatomy, Mahatma Gandhi Mission Medical college, Kamothe, Navi Mumbai on 35 embalmed adult human cadavers. All the dissected cadavers were in the age group of 50 to 70 years. The cadavers with any surgery done in the area to be dissected were excluded from the study.

The dissection of the superior mediastinum by opening the rib cage was done following the steps given in the *Cunningham's manual of practical anatomy*(volume 2,1993) and (volume 3,1993). For the dissection of the superior mediastinum the manubrium sterni was cut transversely below the 1st chondrosternal joint. The ribs were cut in the anterior axillary line and the anterior wall of the rib cage turned downwards.

The clavicles were cut at the junction of the medial and middle1/3rd and the manubrium reflected upwards. The aortic arch and its-branches were dissected and cleaned as per Grant's dissector (2009). The branching pattern of the arch was observed

RESULTS AND OBSERVATIONS

In 31 (88.57 %) cadavers, the arch had the normal branching pattern , that is, three branches, brachiocephalic trunk (BCT) , left common carotid artery(LCCA) and left subclavian artery (LScA), from right to left.

In 4 (11.43 %) cadavers a variation in the branching pattern was noticed.

3 (8.58 %) cadavers showed arch having only two branches. BCT and LCCA arising as a common trunk (CT) from the arch, with LScA as the second branch, to the left of the common trunk. 1 (2.85 %) cadaver had 4 branches arising from the arch. From right to left, these were, BCT, LCCA , left vertebral artery (LVA) and the LScA. The LVA was confirmed by dissection till its entry in the foramen transversarium.

The variations

The common trunk (Figure 1)

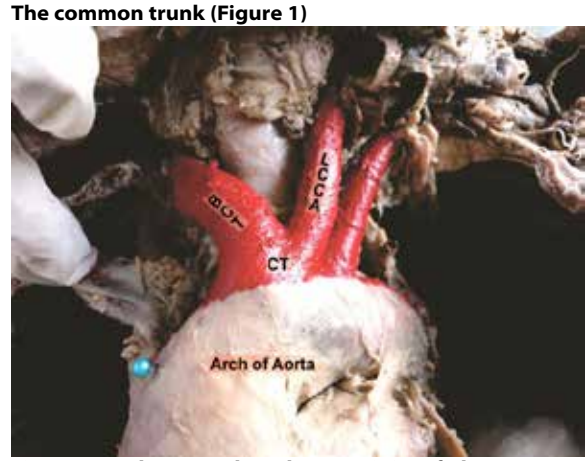

Figure 1 : Photograph : Shows origin of the common trunk from the arch

3(8.58%) cadavers were found to have origin of the BCT and the LCCA from a common trunk (CT) arising from the arch of aorta as seen in figure 1.

The LVA arising from arch (Figure 2)

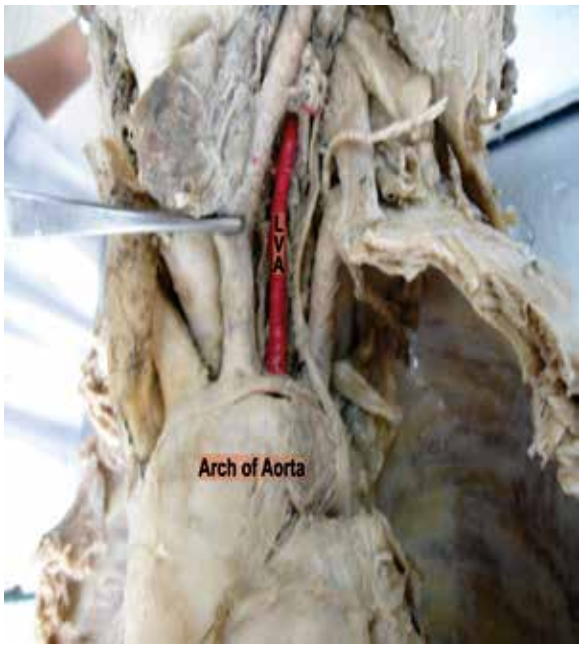

Figure 2 :Photograph : Shows origin of LVA from the arch

Out of 35 cadavers, 1(2.85%) specimen showed 4 branches arising from the arch as seen in figure 2.

The artery arising from the arch between the origins of the LCCA and LScA was left vertebral artery directly taking origin from the arch. This was confirmed by tracing the artery till its entry into the foramen tranversarium. It was also confirmed by dissection that, the left subclavian artery did not give origin to a separate vertebral artery.

DISCUSSION

Thorough knowledge of the arch of aorta, its normal and variant branching pattern is of utmost importance to the radiologists and cardiovascular surgeons to avoid accidental injury to any of these important vessels during surgery.(Dagenais F,2011)

The arch of aorta

Branching pattern

The development ofthe arch and its branches from multiple sources-forms a basis for increased number of chances of variations in the population.

Normally the arch of aorta develops from the left horn of the aortic sinus, the left fourth branchial arch artery and the left dorsal aorta up to the origin of the left seventh intersegmental artery. The brachiocephalic trunk develops from the right horn of the aortic sinus. The common carotid arteries develop from the third branchial arch artery on each side. The left subclavian artery is derived from the left seventh intersegmental artery

According to Shivkumar et al (2010), variant branching pattern can alter cerebral hemodynamics leading to cerebral abnormalities. The knowledge of these variations is important in the diagnosis of the intracranial aneurysm after subarachnoid hemorrhage. In aortic arch surgeries these anomalies should be predetected. For example, ligation of the common carotid artery (CCA) can compromise posterior cranial fossa blood supply if anomalous vertebral artery is originating from the CCA.

According to*Gray's anatomy.38th ed*. (1995 p.1513) and *Clinically oriented anatomy* (2010, p. 174) the normal branching pattern is present in 65 % of the population.

The present study has found normal branching pattern in 31 cadavers,that is (88.57 %) as shown in the following chart.

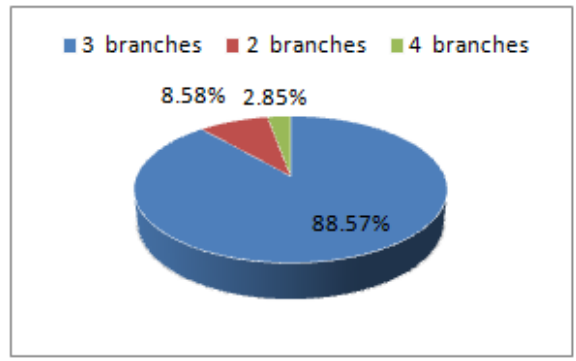

Chart : Shows branching pattern of the arch

Shin Y, Chung Y, Shin WH, Im SB, Hwang SC, Kim BT (2008), have reported a similar pattern with normal branching seen in 84 % of the cases.

Haifa AA and Ramadan WS (2010) report normal pattern in 75 % of the cases, while Adachi B (1928)has shown it to be present in 80 % of the cases.

Anson BJ, Mcvay CB (1971) has found it in 64.9 % and.Ogengo'o JA, Olabu BO, Gatonga PM, Munguti JK (2010) in 67.3%.

One study by Rekha P and Senthilkumar S.(2013), reports normal pattern in 92.72 % of the hearts.

The present study has not taken into consideration any differences according to age, race or sex variations.Williams GD and Edmonds HW (1935) have found difference in percentage of variation in white and black race. They found that 39.8 % blacks showed variant pattern while it was variant in only 21.4 % whites.

Indumathi S, Sudha S, Rajila HSR (2010), in their study report normal branching pattern in 89.1% males and in 88.8 % females. This shows that variations in males and females are comparable and there is not much sex variation.

In a study by Faggioli GL, Ferry M, Freyrie A, Garguilo M, Fratesi F, Rossi C (2007), 88.3 % had normal branching pattern. He found common trunk for BCT and LCCA in 10.2 % cases. He has reported that in CAS procedures technical failure and neurological complications rate was higher in arch anomaly group.

There are also rare but interesting anomalous branching patterns reported in the literature. One such pattern is reported by Wiedemann D, Kocher A, Mahr S, Longato S, Bonaros N, Schachner T.(2013) in which they found no BCT , LCCA as a branch of the ascending aorta , RCCA as the first and RScA as the second branch arising from the arch and LScA as a branch of the descending aorta.

Variations

Common trunk

BCT and LCCA originated as a common trunk in 3 cadavers (8.58 %).

Beigelman C, Mourey-Gerosa I, Gamsu G, Grenier P.(1995) found this variation in 8% cases which is similar to the results of the present study.

Haifa AA and Ramadan WS (2010), has reported common trunk in 25% of the cadavers which is quite high as compared to the present study.

Embryological explanation

Normally right horn of aortic sac develops into the BCT while the left horn becomes part of the arch of aorta. The two corresponding 3rd arch arteries become the common carotid arteries (CCA). If the left horn of the aortic sac gets absorbed in the right horn then the LCCA may arise as a common trunk with BCT or it may be seen as a branch from the BCT. (Manyama M, Rambau P, Gilyoma J, Mahalu W, 2011)

According to Indumathi S. et al (2010) common trunk is more liable

to cause tracheal compression as it always originates to the left of the mid-vertebral plane.

Rob and Smiths' operative surgery, vascular surgery.(5th ed,1994, p.141) states that a common trunk giving origin to BCT and LCCA is a contraindication for the procedure of the BCT endarterectomy.

Left vertebral artery with an abnormal origin

In 1 (2.85 %) cadaver the LVA took origin from the arch directly between the origins of the LCCA and the LScA. This variation is reported to be up to 5 % in the literature and our finding is within that range.

According to study by Ughade JM et al (2012) the possibility of this variation ranges from 1.6 – 7%. In his own study he found the LVA coming from the arch in 5% of the cases.

Study by Haifa AA and Ramadan WS (2010), found this variation in 5.55% of the cases.

Bhatia K, Gabriel MN, Henneberg M (2005)reports higher, 13.95 % , incidence of anomalous LVA in south Australian population who were born in south Australia and not immigrants.

Ogengo'o JA et al (2010) in their study report that when LVA is arising from the arch, it is proximal to the LScA in 28.6% and distal to the LScA in 71.4 % cases.

Embryological explanation

Four parts of the LVA, from its origin on LScA to its termination as the basilar artery, develop from four different sources.

The first part, from its origin to its entry in the foramen transversarium (normally 6th cervical vertebra), develops from the dorsal branch of the left 7thintersegmental artery.

One of the possible reasons for its anomalous origin directly from the arch of aorta could be persistence of the left sixth or even higher intersegmental artery which normally disappears.(Ughade JM et al, 2012)

Other reason for such anomaly could be absorption and incorporation of the proximal part of the left 7thintersegmental artery prior to its dorsal branch into the developing aortic arch.(Manyama M et al, 2011)

According to Komiyama M, Morikawa T, Nakajima H, Nishikawa M, Yasui T (2001)the LVA of aortic origin is associated with a predilection for vertebral artery dissection in comparison to LVA of the subclavian artery origin.

LVA of the aortic origin alters the cerebral hemodynamics predisposing such individuals to cerebral disorders and atherosclerotic changes. (Ughade JM et al, 2012)

Even when not hypoplastic the artery has the smallest diameter as compared to the other branches of the arch. The LVA is thus obscured by the other larger branches of the arch making its preoperative detection by radiology more difficult. The LVA coming from the arch can be diagnosed in only 40 % of the cases.(Ughade JM et al, 2012)

Shin Y et al (2008) reports that the origin of LCCA from the common trunk and the origin of LVA from the arch directly, should be always considered as a possibility by the endovascular surgeons when these vessels are not visualized during surgery.

Aortogram may be necessary in these cases.

Conclusion

In the present study The arch showed normal branching pattern in 88.57% and variant pattern in 11.43% cadavers.

As a variant, 3 cadavers (8.58%) showed only two branches originating from the arch with a common trunk for BCT andLCCA.

One cadaver (2.85%) showed arch with 4 branches giving direct origin to left vertebral artery between LCCA and LScA.

The LVA of the aortic origin is of significance as it is more prone for arterial dissection and alters the cerebral hemodynamics increasing the risk of cerebral disorders.

Cadaveric study gives better three dimensional understanding of these vessels. The knowledge thus gained will be useful to the cardiologists, cardiothoracic surgeons and radiologists in various diagnostic and therapeutic procedures.

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