Embryological relevant variations in the branching pattern of arch of aorta

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SUMMARY

Anatomical variations of the arch of the aorta including its branching pattern are important for diagnostic, surgical, and interventional procedures of the thorax and neck, and the aim of the study is to analyze the anatomical variations of the arch of the aorta in correlation with the development of the arch of the aorta. The purpose of this study is to review the anatomical variations including its branching pattern of the arch of the aorta in fifty adult human cadavers (M: 42, F: 8) dissected in the department of anatomy, Siddhartha Medical College, Vijayawada, for five consecutive years from 2013 to 2018. The arch of the aorta was left sided in all the 50 cadavers. The three branches of the arch of the aorta were normal in 41 cadavers in the present study. In 9 cadavers, variations were observed. In four male cadavers and in a female cadaver, the two branches of the arch of the aorta were the common trunk of the brachiocephalic trunk and the left common carotid artery along with the left subclavian artery. In two male cadavers, the branches were four, including the extra origin of the left vertebral artery from the arch of the aorta. In a female cadaver, the three branches of the arch of the aorta were as follows: the common trunk of the brachiocephalic trunk and the left common carotid artery, the left vertebral artery and the left subclavian artery. In a male cadaver, the four branches were the one additional branch of the right subclavian artery as its fourth branch of the arch of aorta. Head-and-neck surgeons and interventional radiologists should be aware of the variations of the arch of the aorta. Computed tomography angiography is a reliable imaging method for demonstrating the variations of the arch of the aorta.

Key words: Arch of aorta – Brachiocephalic trunk – Left common carotid artery – Left subclavian artery – Left vertebral artery

INTRODUCTION

In the classical anatomical configuration, the arch of the aorta is left sided and the most common branching pattern of the arch comprises three branches from right to left: the brachiocephalic trunk, the left common carotid artery, and the left subclavian artery. The brachiocephalic trunk branches into the right subclavian artery and the right common carotid artery behind the right sternoclavicular joint. This branching pattern occurs only in 64.9% to 94.3% of the cases (Jakanani et al., 2010). The purpose of this study was to clearly review the anatomical variations of the arch of the aorta, including its branching pattern in 50 dissected adult human cadavers in our

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department of anatomy, in correlation with its embryological significance.

The development of the arch of the aorta takes place during the third week of gestation. Six pairs of aortic arches, the so-called pharyngeal arch arteries, develop between the ventral and dorsal aortae. The variations of the aortic arch can be explained by the persistence of segments of the aortic arches that normally regress, or by the disappearance of segments that normally remain, or both (Nayak et al., 2006). The anatomical variations in the branching pattern of the arch of the aorta are significant for diagnostic and surgical procedures in the thorax and neck.

MATERIALS AND METHODS

After approval of the institutional ethical committee, during the routine educational dissection for the undergraduate students in the department of anatomy, Siddhartha Medical College, Vijayawada, in the academic years between 2013 and2018, the anatomical variations in branching pattern of the arch of the aorta in fifty adult human cadavers (M: 42, F: 8) were observed carefully after following the standard dissection procedures. The variations of the arch of the aorta, including its branching, pattern were noted and photographed.

RESULTS

The arch of the aorta was left sided in all the 50 cadavers. The three branches of the arch of the aorta were normal in 41 cadavers in the present study. In 9 cadavers, variations were observed. In five male cadavers and in a female cadaver, the two branches of the arch of the aorta were the common trunk of the brachiocephalic trunk and the left common carotid artery and the left subclavian artery (Fig. 1). In two male cadavers, the branches were four, including the origin of left vertebral artery from arch of aorta (Fig. 2). In a female cadaver, the three branches of the arch of the aorta were as follows: the common trunk of brachiocephal-

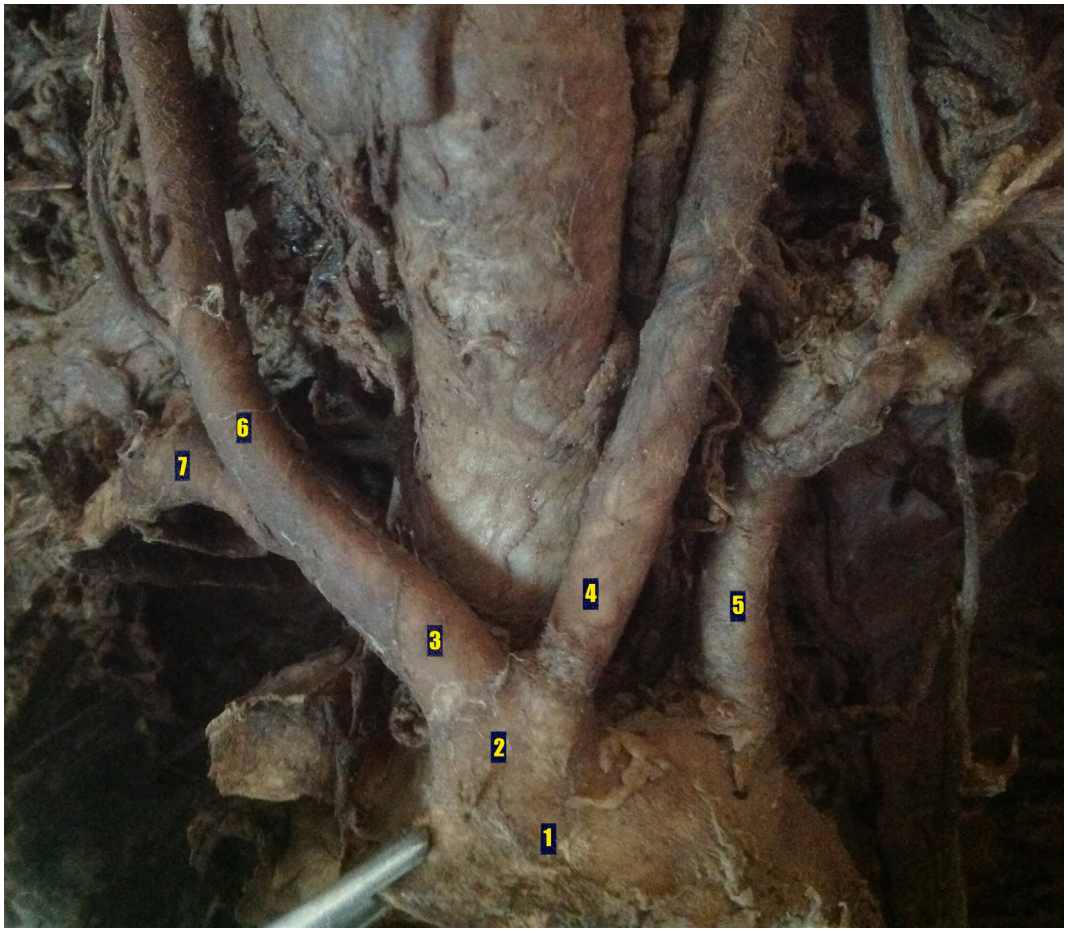

Fig. 1.- Two branches of arch of aorta: common trunk of brachiocephalic trunk and left common carotid artery, left subclavian artery. 1- Arch of aorta. 2- A common trunk of brachiocephalic trunk and left common carotid artery. 3-Brachiocephalic trunk. 4- Left common carotid artery. 5- Left subclavian artery. 6- Right common carotid artery. 7- Right subclavian artery.

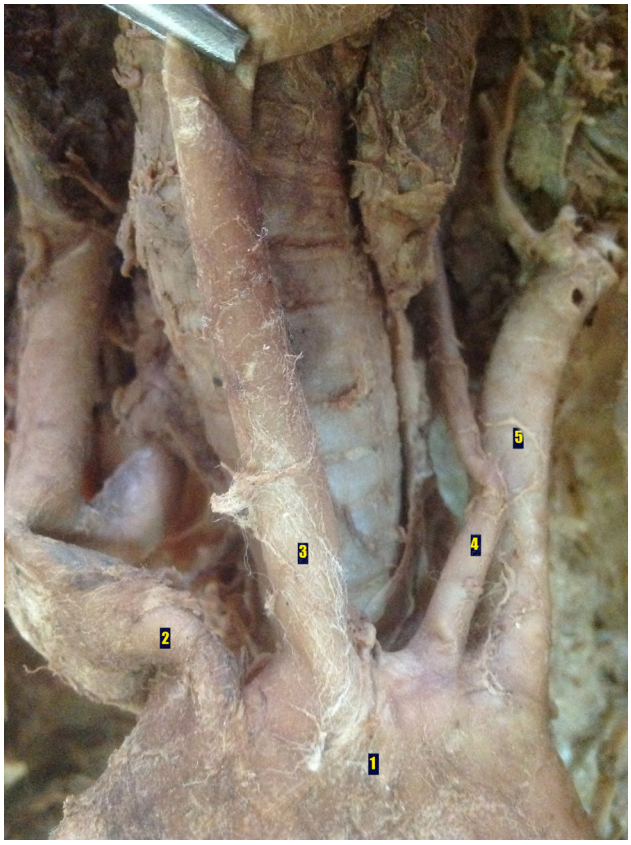

Fig. 2.- Four branches of arch of aorta: brachiocephalic trunk left common carotid artery, left vertebral artery, left subclavian artery. 1- Arch of aorta. 2-Brachiocephalic trunk. 3- Left common carotid artery. 4- Left vertebral artery. 5- Left subclavian artery.

ic trunk and the left common carotid artery, the left vertebral artery and the left subclavian artery (Fig. 3). In this cadaver, the left vertebral artery was arising by two limbs: one limb from the arch of the aorta and the other limb from the descending thoracic aorta. Both limbs joined and entered the foramen transversarium of C6. In a male cadaver, the four branches were the one additional branch of the right subclavian artery as its fourth branch of the arch (Fig. 4).

DISCUSSION

Congenital abnormalities of the arch of the aorta include left-sided, right-sided, and double aortic arches, with various branching variations of the great vessels (Hanneman et al., 2016). The sidedness of the arch of the aorta refers to which bronchus is crossed by the arch. James Stewart et al. classified abnormalities of the arch of the aorta into four major groups: Group I, double aortic arch; Group II, left aortic arch; Group III, right aortic arch; and Group IV, other and rare malformations of the aortic arch (Li et al., 2019). The arch of the aorta normally develops from three sources: the left limb of the aortic sac, the left fourth aortic arch and the part of the left dorsal aorta between the left fourth and sixth aortic arches (Kadir, 1991). The arch of the aorta was left sided in 100% of cases and no other variations like double or interrupted aortic arches were observed in the present study. Muller et al. (2011) studied the images of 2033 contrast CT scans of the arch of the aorta and observed right sided arch in a single case.

In the present study, the normal branching pattern of the left-sided arch of the aorta was observed in 82%, and in 18% of cases the arch of the aorta showed variations. The normal three-branch pattern of the arch of the aorta is found with an incidence of 83% (Natsis et al., 2009). In the

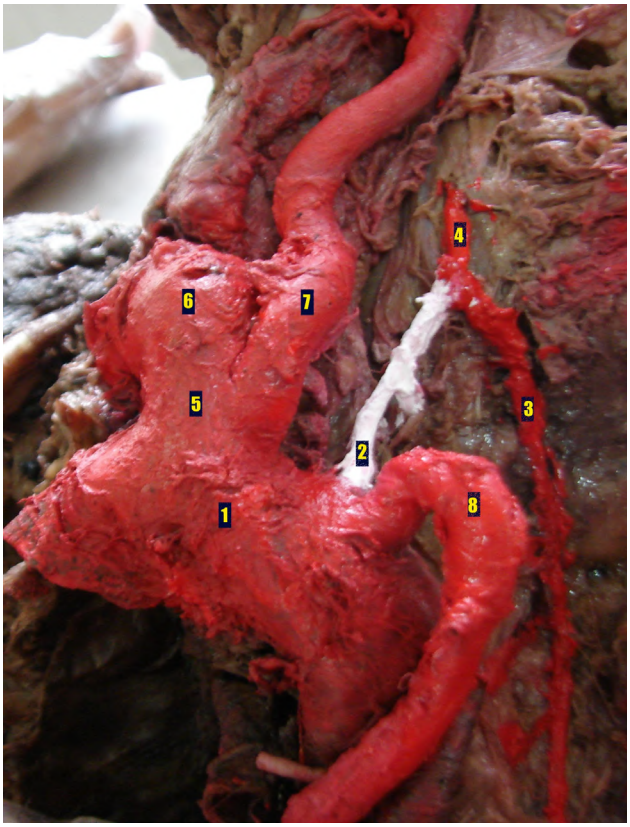

Fig. 3.- Three branches of arch of aorta: common trunk of brachiocephalic trunk and left common carotid artery, left vertebral artery, left subclavian artery. Left vertebral artery is arising by two limbs — one limb from the arch of aorta and the other limb from the descending thoracic aorta. 1- Arch of aorta. 2- One limb of origin of left vertebral artery from arch of aorta. 3- Another limb of left vertebral artery from descending thoracic aorta. 4- Left vertebral artery. 5- A common trunk of brachiocephalic trunk and left common carotid artery. 6- Brachiocephalic trunk. 7- Left common carotid artery. 8- Left subclavian artery.

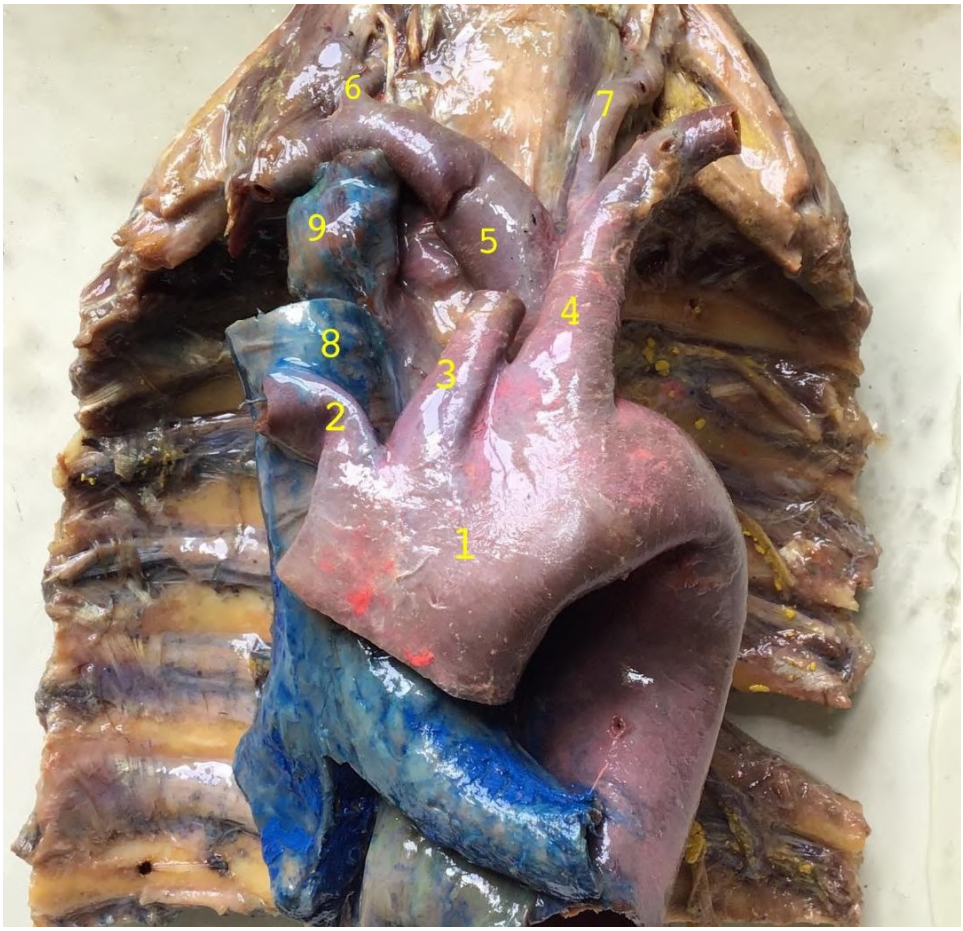

Fig. 4.- Four branches of arch of aorta: brachiocephalic trunk, left common carotid artery, left subclavian artery, right subclavian artery. 1- Arch of aorta. 2- Brachiocephalic trunk. 3- Left common carotid artery. 4- Left subclavian artery. 5- Right subclavian artery. 6- Right vertebral artery. 7- Left vertebral artery. 8-Pulmonary trunk. 9- Right brachiocephalic vein.

meta-analysis of imaging studies of the left-sided aortic arch variants in 18,075 cases, the normal branching pattern of the arch of the aorta was observed in 77% (Tsiuoris et al., 2022). In the analysis of 1000 computed tomography angiograms, the normal branches of the arch of the aorta were present only in 65.9% (Berko et al., 2009).

Adachi (1928) classified for the first time the branching pattern of the arch of the aorta in three types: Type A: normal three branches of the arch of aorta; Type B: two branches of common trunk of brachiocephalic and right common carotid artery and the left subclavian artery; Type C: origin of the left vertebral artery from the arch of the aorta apart from its three normal branches. Karacan et al. (2014) studied the anatomical variations of the arch of aorta with computed tomography angiography in 1000 patients and found that 20.8% had variations: Type I: normal branching pattern (79.2%); Type II: brachiocephalic and left common carotid arteries arising from the arch in a common trunk (14.1%); Type III: left vertebral artery originating from the arch (4.1%), Type IV: coexistence of type II and type III (1.2%); Type V: aberrant right subclavian artery(0.6%), Type VI: coexistence of aberrant right subclavian artery and bicarotid trunk(0.7%) and Type VII: thyroidea ima artery arising from the arch (0.1%). In the present study, the incidence of type 1 is 82%, of type II is 12%, of type III is 4%, of type IV is 2%, and of type V is 2%.

The most common variation of the arch of the aorta, also called bovine arch, is the two-branch type of the common trunk of the brachiocephalic and left common carotid artery and the left subclavian artery, with an incidence of 10% to 25% (Layton, 2006), which was 12% in the present study. Developmentally, the two-branch pattern of the arch of the aorta may be explained as follows: the aortic sac normally bifurcates into left and right limbs. The left limb of the aortic sac forms the part of the arch that intervenes be-

tween the origin of the brachiocephalic trunk and left common carotid artery. If the aortic sac fails to bifurcate, then the left common carotid artery will connect to the aortic sac directly, resulting in the common trunk giving origin to the brachiocephalic trunk and the left common carotid artery (Poultsides, 2004). In the study of the correlation between the bovine arch and the risk of cardiothoracic disease, the ratio of risk was more in the patients with bovine arch than in patients with the normal pattern of the arch of the aorta (Marrocco-Trischitta et al., 2019). Hornick et al. (2012) studied the association of patients having bovine arch for the thoracic aortic diseases, and found a significant increase in the risk, including the accelerated aortic growth rate.

The origin of the left vertebral artery from the arch of aorta is between 0.79% to 8% (Liechty, 1947), and this variation was observed alone in 4% and associated with the bovine arch in 2% in the present study. The origin of the left vertebral artery was between the left common carotid artery and the left subclavian artery in all the cases in this study. In the study of Muller et al. (2011), the origin of the left vertebral artery from the proximal part of the arch of the aorta is 4.2%, and the origin of the left vertebral artery from the arch of the aorta distal to the origin of the left subclavian artery in a single case. Embryologically, it is explained that this is due to the fact that the left vertebral artery develops from the persistent sixth cervical intersegmental artery (Nayak et al., 2006). The incidence of bovine aortic arch with the aberrant origin of the left vertebral artery from the arch of the aorta with the VACTERL association (vertebral, anal, cardiac, tracheoesophageal, renal and limb malformations) has been reported in a three-year-old boy by Martínez-García et al. (2024).

Komiyama et al. (2001) reported in their study that two patients had dual origin of the left vertebral artery, with one limb originating from the aorta and another limb from the left subclavian artery. Satti et al. (2007) also reported in their study about the origin of the left vertebral artery with two limbs, one originating from aortic arch and other from the left subclavian artery in digital subtraction angiography. But, as in the present study, the origin of the left vertebral artery by two limbs, with one limb from the arch of the aorta and the other limb from the descending thoracic aorta, is rarely reported.

In a study based on 400 dissections by Dasler et al. (1959), an aberrant right subclavian artery arising from the arch of the aorta distal to the left subclavian artery is of 0.25%. The aberrant origin of the right subclavian artery is caused by the disappearance of the right fourth aortic arch and proximal right dorsal aorta, and the persistence of the seventh cervical intersegmental artery originating from the proximal descending thoracic aorta, forming the abnormal course of the aberrant artery (Inami et al., 2013). Left-sided arch of the aorta with aberrant right subclavian artery causes dysphagia lusoria (Bayford, 1787).

Arch variants that form vascular rings, such as double aortic arch, cause respiratory distress by compression of the trachea. Abnormalities of the arch of the aorta are strongly linked with congenital heart disease, and even genetic associations like the type B interrupted aortic arch is associated with a locus 22q11.2 microdeletion. Echocardiography, cardiac magnetic resonance imaging, and computed tomography angiography are important imaging modalities used to diagnose aortic arch variations in the adults. Congenital abnormalities of the arch of the aorta are important to recognize earlier whether they are associated with vascular rings, congenital heart disease and chromosomal abnormalities, which can have important implications in planning the management of surgical and percutaneous interventions of the thorax (Hanneman et al., 2016).

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