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Anatomical variations in the branching pattern of human aortic arch: a cadaveric study from Nepal

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SUMMARY

Variations of the branches of the aortic arch are due to alteration in the development of certain branchial arch arteries during the embryonic period. Knowledge of these variations is important during aortic instrumentation, thoracic, and neck surgeries. In the present study we observed these variations in forty-two cadavers from Nepal populations. In thirty-five (83.3%) cadavers, the aortic arch showed a classical branching pattern which includes brachiocephalic trunk, left common carotid artery, and left subclavian artery. In seven (16.7%) cadavers it showed variations in the branching pattern, which include the two branches, namely, left subclavian artery and a common trunk in 2.4% cases, four branches, namely, brachiocephalic trunk, left common carotid artery, left vertebral artery, and left subclavian artery in 11.9% cases, and the four branches, namely, right common carotid artery, left common carotid artery, left subclavian artery and right subclavian artery in 2.4% cases.

Key words: Variation – Aortic arch – Mid-vertebrae line

INTRODUCTION

The arch of the aorta is a continuation of the ascending aorta, located in the superior mediastinum. Three branches – the brachiocephalic trunk, the left common carotid artery, and the left subclavian artery – usually arise from the arch of aorta. The brachiocephalic trunk later divides into the right common carotid and the right subclavian artery (Standring, 2005). Most of the anomalies of the arch of the aorta and its branches are as a result of an altered development of primitive aortic arches of the embryo during the early gestation period (Nurru et al., 2009). Understanding the great vessels of the aortic arch and their variations is important for both endovascular interventionists and diagnostic radiologists. Increasing activity in the fields of cardiac and vascular surgery has revived interest in the developmental anatomy, especially in the aortic arches and its derivatives. An understanding of the variability of these arteries remains most important in angiography and surgical procedures where an incomplete knowledge of anatomy can lead to serious implications. This has become more important in the era of carotid artery stents, vertebral artery stents, and therapeutic options for intracranial interventions (Poonam et al., 2010).

MATERIALS AND METHODS

A study was therefore conducted in the Department of Anatomy, National Medical College & Teaching Hospital, Birgunj, Tribhuvan University (Nepal), to study the branching pattern of the arch of the aorta. 42 cadavers (30 male and 12 female cadavers) were included in the study. The dissection of the thoracic region was carried out according to the instructions by Cunningham's Manual of Practical Anatomy (Vol. 2). The dissections took place during the years 2012-2014. The formalin-based preservative (10% formalin) preserved the body at -4°C. The thoracic cavity was exposed;

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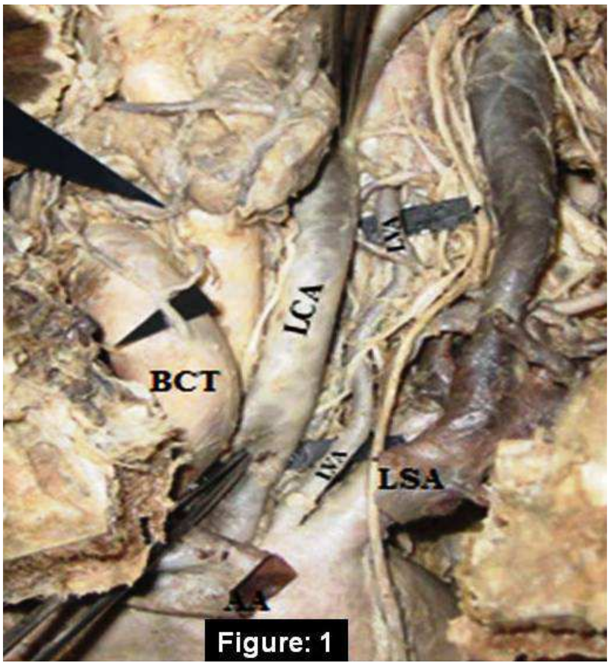
lungs were removed, the superior vena cava and brachiocephalic veins cleared, and the pericardium was uncovered to expose the ascending aorta. Fibro-fatty tissue and nerves were removed to clarify the branches of the arch of the aorta. The arteries were painted and allowed to dry and then photographed. Photographs of the variant anatomy of the aortic arch were taken using a digital camera (Sony© - 12.1 megapixel, modal no. - 5602533). The variant patterns were tabulated (Table 1). No additional anomalies or pathological changes were found on the remainder of vessels and other organs of the thoracic cavity of the same cadaver.

RESULTS

In the present study 35 (83.33%) (25 male and 10 female) cases showed a normal branching pattern, and variations were found in 7 (16.66%) (5 male and 2 female) cases. The arterial pattern was congregated into four categories based on the frequencies of variations (Vicurevic et al., 2012) (Table 1).

1. Type I 35 cases (83.33%): Normal pattern
2. Type II 05 cases (11.90%): An aberrant origin of the left vertebral artery (LVA), which showed a typical vessel arrangement (the BCT, LCCA, LSCA) with the LVA origin between the LCCA and LSA. The left vertebral artery was also arising from the arch of the aorta in addition to the other normal branches (Fig. 1).
3. Type III 01 case (02.38%): Only two branches were seen to arise from the arch of the aorta i.e., a common brachiocephalic trunk (CBT), branching into brachiocephalic trunk and left common carotid artery. The LCCA and BCT shared the same site of origin and the LSA was originated from the aor-



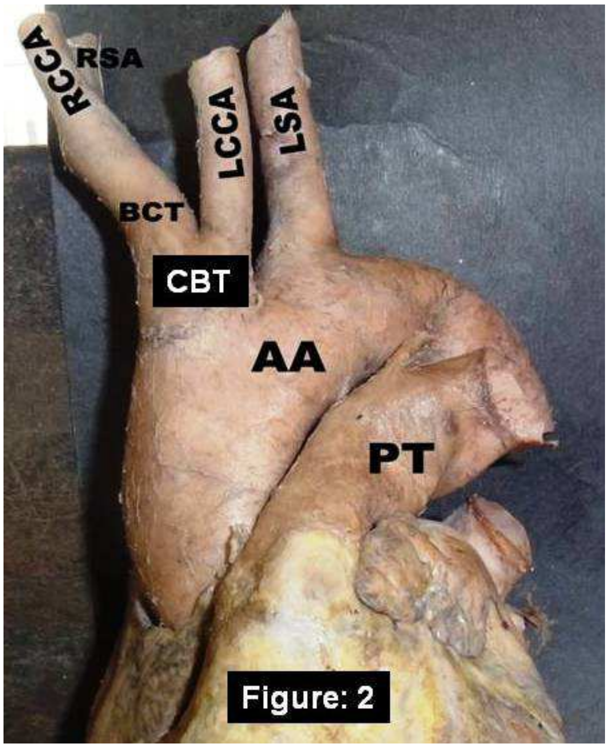


Figure 1. The Left Vertebral Artery (LVA) branching out from the Arch of Aorta (AA) between Left Common Carotid (LCCA) and Left Subclavian Artery (LSA). BCT, brachiocephalic trunk,; RCCA, right common carotid artery; RSA, right subclavian artery; PT, pulmonary trunk; RA, right atrium.

Figure 2. A Common Brachiocephalic Trunk (CBT) branching into brachiocephalic trunk (BCT) and left common carotid artery (LCCA). The left subclavian artery (LSA) arising separately from the arch of aorta (AA). RCCA, right common carotid artery; RSA, right subclavian artery; PT, pulmonary trunk; RV, right ventricle; LV, left ventricle.

Table 1. Types of variations in the arch of aorta

Type	Number of Branches	Description of Branches	Frequency	Percentage (%)
I	3	BCT, LCCA, LSA	35	83.33
II	4	BCT, LCCA,LVA,LSA	5	11.90
III	2	CT (BCT,LCCA),LSA	1	2.38
IV	4	RSA, RCCA, LCCA, LSA	1	2.38
	Total		42	100

BCT (Brachiocephalic Trunk); CBT (Common Brachiocephalic Trunk); LCCA (Left Common Carotid Artery); LSA (Left Subclavian Artery); LVA (Left Vertebral Artery); RSA (Right Subclavian Artery); RCCA (Right Common Carotid Artery).

Table 2. Incidence of the types of variations in the branching pattern of the arch of aorta

Type	Adachi et al. (1928) (%)	Mc Donald and Anson (1940) (%)	Mc Donald and Anson ((1940) (%)	Natsis et al. (2009) (%)	Nayak et al. (2006) (%)	Present study (%)
I	83.3	66.9	51.7	83	91.4	83.33
II	4.3	1.46	--	0.79	1.6	11.90
III	10.9	25.5	41.4	15	4.8	2.38
IV	0.8	--	1.7	0.16	1.6	2.38
Population	516 Japanese	157 American White	59 American Black	633 Greek	62 Indians	42 Nepalese

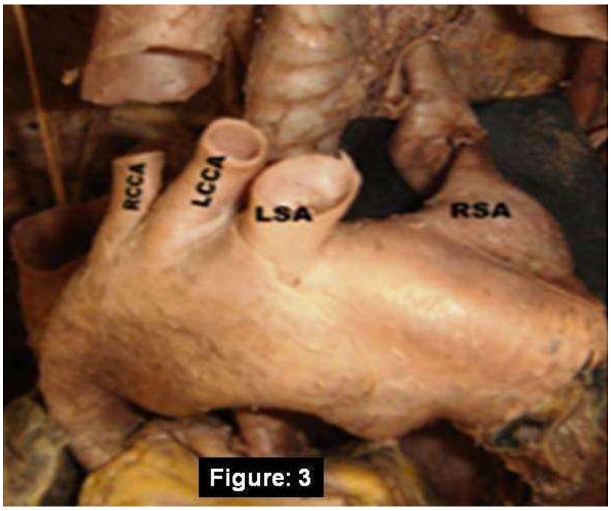


Figure 3. The Right Subclavian Artery (RSA) branching out from the Arch of Aorta and the Brachiocephalic Trunk (BCT) is absent. RCCA, right common carotid artery; LCCA, left common carotid artery; LSA, left subclavian artery.

tic arch as the most distal branch (Fig. 2).

4. Type IV 01 case (02.38%): Absence of the brachiocephalic trunk with the right subclavian and right common carotid arteries arising directly from the arch of the aorta. The anomalous right subclavian artery ran obliquely from left to the right side between the oesophagus and the vertebral column to reach the right upper limb. This is called arteria lusoria. All of them had the RSA as a distal aortic branch (Fig. 3).

DISCUSSION

Variations of the great arteries in the thoracic region are well known and the aortic arch is one of them. Aortic arch anomalies may also be attributed to chromosomal abnormalities. Momma et al. (1999) noted that aortic arch anomalies are associated with chromosome 22q11 deletion.

The variations of the branches of the arch of the aorta are usually associated with abnormalities of the heart and persistent foetal conditions. Many variations are due to differences in the mode of transformation of aortic arch vessels from the branchial arches, especially from the fourth arch. Since the aorta and pulmonary artery develops from a common conus arteriosus, irregular and imperfect development of the septum between them may also produce variations (Bergman et al., 1996).

Reported variations in the aortic arch branching pattern include left common carotid artery originating from the brachiocephalic trunk; right common carotid artery and right subclavian artery originating individually from the aortic arch (Anson, 1963; Shiva Kumar et al., 2010). Additionally, the left common carotid and the left subclavian artery may have a common origin as the left brachiocephalic trunk (Double brachiocephalic trunk) from the aortic arch. The left vertebral artery may also arise between the left common carotid artery and the left subclavian artery (Nayak et al., 2006).

In the present study 35 cases (83.33%) showed a normal branching pattern i.e., the brachiocephalic trunk, the left common carotid artery, and the left subclavian artery and the variations were found in 16.66% of the cases. These variations are likely to occur as a result of differential development of certain branchial arch arteries during the embryonic period of gestation (Natsis et al., 2010). The type I arterial arrangement represents the normal branching pattern of the arch of the aorta, reported in 83.33% of the cases. This is in close agreement with the studies have done by various authors (Table 2).

The current study reveals 05 cases (11.90%) of Type-II pattern i.e., the left vertebral artery arising from the arch of aorta in addition to the other normal branches. This suggests that part of the arch of the aorta may be arising from the 7^{th} intersegmental artery or may be due to increased absorption of embryonic tissue of the left subclavian artery between the arch of the aorta and the vertebral artery (Moore et al., 2003). According to Bernardi and Detori, the unusual origin of the vertebral artery may favor cerebral disorders because of alterations in the cerebral hemodynamics (Bernardi et al., 1975). Such anomalies can cause ischemia, as well as infarction of the brain stem and cerebellum if the vertebro-basilar axis is left dominant and communication at the arterial circle of Willis is poor (Yamashiro et al., 2010). Detecting the variations in the origin of the left vertebral artery and other arteries are beneficial in the diagnostic improvements before vascular surgeries of supra-aortic arteries and is also useful in planning aortic arch surgeries or endovascular interventions

(Patasi et al., 2009).

In this study we observed 01 case (02.38%) of Type-III pattern i.e., two branches arising from the arch of the aorta, a common brachiocephalic trunk branching into brachiocephalic trunk and left common carotid artery. The left subclavian artery was however arising separately from the arch of the aorta (Fig. 1). Developmental anomalies in aortic arch branching pattern arise from unusual patterns of development of the embryonic aortic arch system of the pharyngeal arches, such that there may be persistence of aortic arches that normally disappear or disappearance of parts that normally persist (Moore et al., 2003). The uncommon branching patterns of the aortic arch are due to either persistence of certain aortic arches which should be obliterated normally or viceversa. The proximal part of the third aortic arch normally gets extended and absorbed into the left horn of the aortic sac. If it gets absorbed into the right horn of the aortic sac, it can lead to anomalies where the left common carotid artery arises from the brachiocephalic trunk or the left horn of the aortic sac is fails to develop (Goray et al., 2005; Nayak et al., 2006). There so the left 3^{rd} aortic arch derivatives (LCCA) is directly connected with the right 3rd aortic arch (BCT) or right horn of aortic sac. Similar reports were documented by Natsis et al. (2009), Paraskevas et al. (2008), Gupta and Sodhi (2005), and Satyapal et al. (2003). Accidental occlusion of this common trunk may have major ischemic complications given that it supplies both carotids, right vertebral and subclavian arteries. Further, this variation is associated with cardiac and coronary arterial abnormalities. Understanding the pathophysiological effect of the common trunk is important when planning palliative or corrective procedures and when assessing the potential benefit of surgical repair over the long term (Ogeng'o et al., 2010).

The extremely high incidence of Type II (11.90%) and the relatively low incidence of Type III (2.38%) observed in the current study. The presence of an aberrant origin of the LVA (Type-II) is due to the persistence of left 6^{th} intersegmental artery, which becomes the initial part of the LVA (Nayak et al., 2006; Sadler, 2006). Developmentally, it will be located between the LCCA and LSA in adults. Type-III pattern is the least often to occur in our study. Type-III pattern shows the common brachiocephalic trunk (CBT), branching into the brachiocephalic trunk and the left common carotid artery. The LCCA and BCT shared the same site of origin and the LSA was originated from the aortic arch as the most distal branch. This is due to the left horn of the aortic sac's failure to develop (Goray et al., 2005; Nayak et al., 2006) there, so the left 3rd aortic arch derivatives (LCCA) are directly connected with the right 3^{rd} aortic arch (BCT) or the right horn of the aortic sac.

The other type of aortic arch branching pattern we observed in this study is 01 case (02.38%) of Type-IV pattern i.e., the brachiocephalic trunk was absent with the right subclavian and right common carotid arteries arising directly from the arch of the aorta. The anomalous right subclavian artery ran obliquely from the left to the right side between the oesophagus and the vertebral column to reach the right upper limb (Fig. 3). The origin of the retroesophageal right subclavian artery as the last branch of the aortic arch is often seen as a congenital aortic arch anomaly. The reported frequency of this anatomical variation is about 0.4-2% (Momma et al., 1999). The possible embryological basis of the 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 intersegment artery and from the distal segment of the right dorsal aorta (Moore et al., 2003). As development continues and the arch of the aorta forms, a differential growth shifts the origin of the right subclavian artery closer to the left subclavian artery. Bergman et al. (1996) stated that, the right subclavian artery may arise directly from the arch of the aorta, as the first, second, third, fourth or fifth branch.

Surgical reports from clinical cases show that anomalous arteries are more prone to atherosclerotic degeneration. In elderly patients an anomalous right subclavian artery occasionally becomes tortuous and can compress the trachea or the oesophagus causing dysphagia lusoria (Stone et al., 1990; Kieffer et al., 1994; Azakie, 1998). Whereas, if found in front of the trachea, it may cause complications during tracheostomy. Moreover, an anomalous right subclavian artery may be associated with a diverticulum of the aorta or, it may cause aneurysms (Brown et al., 1993; Bahnson et al., 1950). The anomalous right subclavian artery may be accompanied with variations in the course of the recurrent laryngeal nerve. In such cases the right recurrent laryngeal cannot form a loop around the right subclavian artery and it is called "non-recurrent laryngeal nerve" (Natsis et al., 2009).

CONCLUSION

Clinicians and surgeons should be aware of aortic arch variations. Prior identification of these vascular anomalies through diagnostic interventions are crucial to avoid complications during heart and vascular surgeries. Non-recognition of a critical aortic arch branch variation at surgery may lead to fatal consequences. Knowledge of the embryonic aortic arch system is therefore required to understand the development of anomalous branches arising from the arch of aorta (Karabulut et al., 2010).

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