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Anatomical Variation in Branching Pattern of Arch of Aorta: A Cadaveric Study with Embryological and Clinical Implications.

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ABSTRACT

Developmental anomalies in the branching pattern of arch of aorta are due to unusual development pattern of aortic arch arteries. The present study was carried out on 105 adult human heart specimens which were preserved in 10% formalin, in department of anatomy, DRBVP Rural medical college, Loni. Variations in branching pattern were documented according to different types mentioned by Acar et al in 2013. Normal branching pattern (Type A) was found in 92 specimens (87.62%) and variations in13 (12.38%) specimen. The most common variation was Type B with two branches consisting common trunk of brachiocephalic and left common carotid artery and left subclavian artery was found in 6 (5.71%) specimens. Type D variation with four branches brachiocephalic, left common carotid, left vertebral and left subclavian in 4 (3.81%) specimens. Type E pattern 3 branches with common trunk of brachiocephalic and left common carotid, left vertebral and left subclavian were present in 3 (2.86%) specimens. In type E pattern out of three, in two specimens, the left vertebral artery arose between common trunk and left subclavian artery but in one, the left vertebral artery arose distal to left subclavian artery. The precise knowledge of variation in branching pattern is clinically relevant because of its direct influence on neck or thoracic surgeries and cardiovascular procedures.

Keywords: Aortic variations, Vascular surgery**,** brachiocephalic trunk, left common carotid, left vertebral artery, left subclavian artery

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INTRODUCTION

Arch of aorta is the continuation of ascending aorta and is located in the superior mediastinum. It has three branches: the brachiocephalic trunk (BT), left common carotid (LCC) and left subclavian artery (LSA)[1]. Many researchers observed the variations in branching pattern of arch of aorta. The most common variation is, common trunk of brachiocephalic and left common carotid artery [1]. The separate origin of right common carotid and right subclavian is rare. Also, origin of left common carotid and left subclavian artery from left brachiocephalic trunk is rare and reported by some researchers [2, 3]. There may be origin of left vertebral artery (LVA) between origin of left common carotid and left subclavian artery [1, 4].

These variations are due to developmental anomalies in aortic arch. The developmental anomalies in aortic arch occurs because of 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 [5]. The development of blood vessels is also associated with placental growth factor and also endothelial growth factor A 164/165 [6]. According to Mumma K et al. anomalies of arch of aorta are associated with Chromosomal 22q deletion [7].

The pharyngeal arches developed during the fourth week of gestation. These are supplied by aortic arch arteries derived from aortic sac and these arch arteries terminate into dorsal aorta of ipsilateral side. Usually six arch arteries develop, but not simultaneously. At the time, when sixth arch is developed, the first two arches disappear. The formation of final fetal arterial arrangement is in the eighth week [5].

The development of arch of aorta is from three components: first part between origin of brachiocephalic trunk and left common carotid artery is from left horn of aortic sac, second part between left common carotid and left subclavian artery is from left fourth aortic arch and remaining part from left dorsal aorta up to the fusion of two dorsal aortae. The brachiocephalic trunk develops from right horn of aortic sac. The formation of right subclavian artery is from right fourth aortic arch (forming its root), a small portion of right dorsal aorta, and the right seventh intersegmental artery. The right and left common carotid artery develops from right and left third aortic arch respectively. A bud for external carotid artery arises from common carotid artery and the remaining part of third aortic arch and the part of dorsal aorta forms internal carotid artery of respective side [8, 9].

The left subclavian artery develops from left 7th intersegmental artery and further there is cranial shifting of subclavian artery close to left common carotid artery due to differential growth as the development proceeds [5].

Abnormal branching patterns of aortic arch may adversely affect hemodynamic balance leading to cerebral abnormalities [10]. Complications occurring during open surgery of aortic arch include ischaemic problems, which may be caused by unrecognised variations in vascular anatomy [11].

MATERIAL AND METHODS

Sample size

Sample size was determined by OpeEpi software at 95% confidence level, the calculated sample size was 88. (Source: Results from OpenEpi, Version 3, Open-source calculator—SS Propor)

The present study was carried out on 105 adult human heart specimens which were preserved in 10% formalin, in department of anatomy, DRBVP Rural medical college, Loni after approval of institutional ethical committee. The heart specimens were dissected for proper exposure of arch of aorta and its branches. Variations in branching pattern were documented in the form of different types mentioned by Acar et al in 2013 [12].

Type A: Brachiocephalic trunk (BT), Left common carotid artery (LCC), left subclavian artery (LSA)
Type B: Brachiocephalic trunk and Left common carotid common root, Left subclavian artery.
Type C: Right subclavian artery (RSA), Right common carotid artery (RCC), Left common carotid artery, Left subclavian artery

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Type D: Brachiocephalic trunk, Left common carotid, Left vertebral and Left subclavian artery.
Type E: Common root of Brachiocephalic trunk and Left common carotid, Left vertebral and Left subclavian artery.
Type F: Right subclavian artery, common root of Right and Left common carotid, Left subclavian artery.
Type G: Right subclavian artery, Right common carotid artery, Left internal carotid artery (LICA), Left external carotid artery (LECA) and Left subclavian artery.

The photographs were taken. The data was tabulated and percentage of heart specimens having variations were computed and analyzed.

OBSERVATION AND RESULTS

Out of 105 adult human heart specimens, 92 specimens (87.62%) showed the normal branching pattern i.e. Type A as per Acar et al. classification and 13 specimens (12.38%) showed different variations. The Type B pattern (Fig1&2) having two branches consisting common trunk of brachiocephalic and left common carotid was observed in 6 (5.71%) specimens, Type D pattern (Fig 3,4 & 5) was observed in 4 (3.81%) specimens having brachiocephalic trunk, left common carotid, left vertebral, and left subclavian artery. The Type E pattern was found in 3 (2.86%) specimens with common trunk of brachiocephalic and left common carotid artery, left vertebral and left subclavian artery. Out of that in two specimens (Fig. 6&7) left vertebral artery was in between the Common trunk and left subclavian artery but in one specimen (Fig.8) it was arising from arch of aorta distal and posterior to the left subclavian artery. Also, there was immediate origin of right vertebral artery from right subclavian artery after bifurcation of brachiocephalic trunk (Fig. 8)

Table 1: Variations in branching pattern with percentage according to classification by Acar et al.

Type according to Acar et al. classification	Number of specimens	percentage
Type A (BT, LCCA, LSA)	92	87.62%
Type B (BT and LCCA common root, LSA)	6	5.71%
Type C (RCCA, RSA, LCCA, LSA)	-	-
Type D (BT, LCCA, LVA, LSA)	4	3.81%
Type E (BT and LCCA common root, LVA, SVA)	3	2.86%
Type F (LCCA and RCCA common root, LSA, RSA.)	-	-
Type G (RCCA, LICA, LECA, LSA, RSA)	-	-

Figure 1: Type B variation, Two branches of arch of aorta with one Common trunk (1. CT) of brachiocephalic trunk (BT) and left common carotid artery (LCC), and Left subclavian artery (2.LSA).

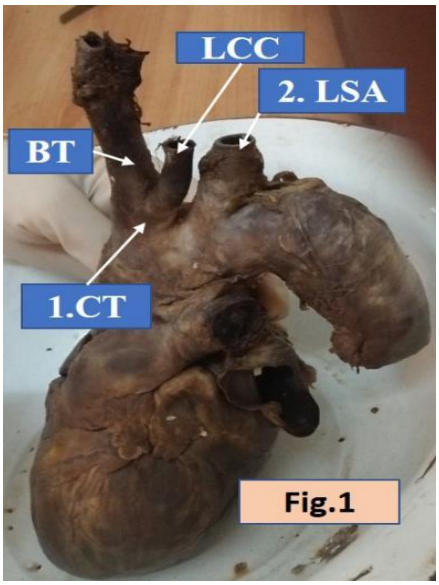

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Figure 2: Type B variation, Two branches of arch of aorta with common trunk (CT)of brachiocephalic trunk (BT) and left common carotid artery (LCC), and Left subclavian artery (LSA).

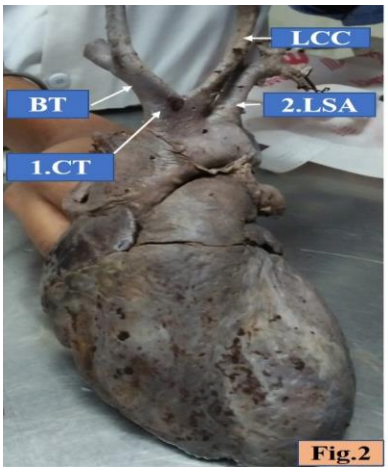

Figure 3: Type D variation, four branches of arch of aorta, from right to left, Brachiocephalic Trunk (BT), Left common carotid (LCC), Left vertebral artery (LVA) and Left subclavian artery (LSA).

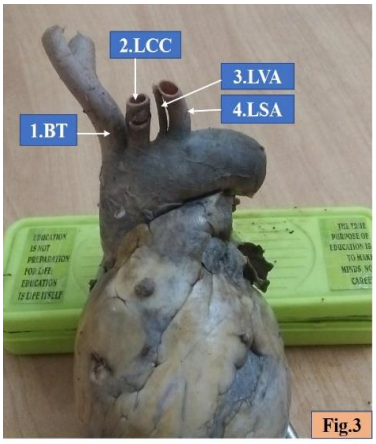

Figure 4: Type D variation, four branches of arch of aorta, from right to left, Brachiocephalic Trunk (BT), Left common carotid (LCC), Left vertebral artery (LVA) and Left subclavian artery (LSA).

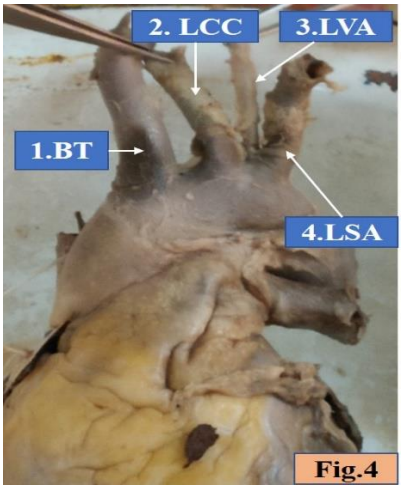

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Figure 5: Type D variation, four branches of arch of aorta, from right to left, Brachiocephalic Trunk (1.BT), Left common carotid (2.LCC), Left vertebral artery (3.LVA) and Left subclavian artery (4.LSA).

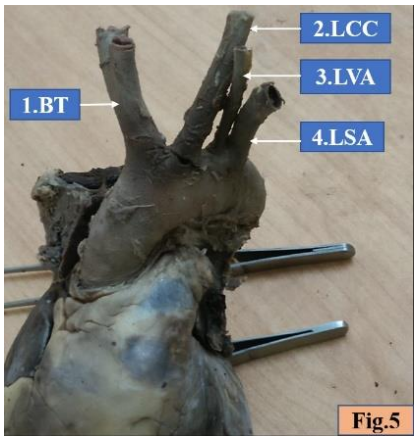

Figure 6: Type E variation, Three branches of arch of aorta, from right to left, Common trunk(1.CT) of Brachiocephalic Trunk (BT)and Left common carotid(LCC),Left vertebral artery(2.LVA) and Left subclavian artery(3.LSA).

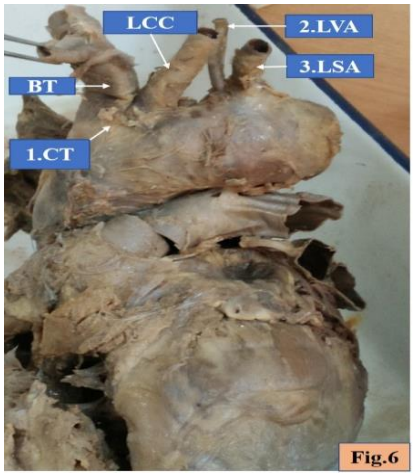

Figure 7: Type E variation, Three branches of arch of aorta, from right to left- Common trunk (1. CT) of Brachiocephalic Trunk (BT)and Left common carotid(LCC),Left vertebral artery(2.LVA) Left subclavian artery(3.LSA).

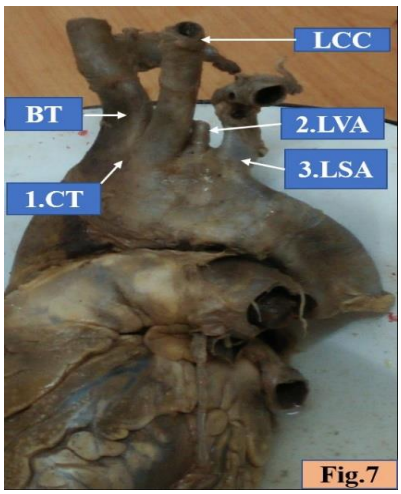

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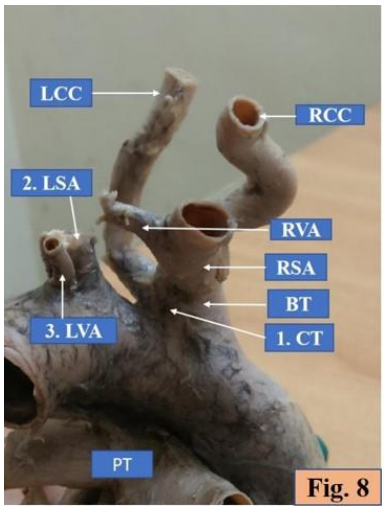
Figure 8: Type E variation (posterior aspect), Three branches of arch of aorta, left to right 1. Common trunk (1. CT) of Brachiocephalic Trunk (BT) and Left common carotid (LCC), 2. Left subclavian artery (2. LSA) and 3. Left vertebral artery (3. LVA) arising from arch of aorta distal and posterior to Left subclavian artery. Right common carotid artery (RCC), Right subclavian artery (RSA), immediate origin of Right vertebral artery (RVA)from right subclavian artery, Pulmonary trunk (PT)



DISCUSSION

Though most of the anatomical variations of arch of aorta have no physiological effect, they may increase the complications during surgical procedures [13]. The precise knowledge of branching pattern of the aortic arch and their anatomical variations is important for both endovascular interventionists and diagnostic radiologists. The knowledge of variations in branching pattern of aortic arch is clinically important in angiography and surgical procedures where lack of knowledge of anatomy can lead to serious implications [14]. Also, these variations are important in the era of carotid artery stents, vertebral artery stents, and intracranial interventions for therapeutic options [15].

Table 2: Incidence of types of variations in branching pattern of arch of aorta according to Accar et al.

Researcher	Sample size	Type A	Type B	Type C	Type D	Type E	Type F	Type G	Other variation
Nayak SR et al [4]. (2006)	62	56 (91.4%)	3 (4.8%)		1 (1.60%)				2 (3.20%)
Alsaif & Ramadan [16] (2010)	36	27 (75%)	6 (16.67%)		2 (5.55%)				1 (2.78%)
Mamatha H et al [17]. (2013)	40	34 (85%)	1 (2.5%)	1 (2.5%)	4 (10%)	-	-	-	-
Acar et al [12]. (2013)	94	70 (74.46%)	14 (14.91%)	4 (4.25%)	2 (2.13%)	2 (2.13%)	1 (1.06%)	1 (1.06%)	
Kumar and Mishra [18] (2015)	42	35 (83.3%)	1 (2.4%)	1 (2.3%)	5 (11.9%)				
Manjappa and Gowd [19]. (2015)	100	82 (82%)	12 (12%)		3 (3%)	2 (2%)			1 (1%)
Tapia GP et al [20]. (2015)	525	440 (83.80%)	62 (11.80%%)	20 (3.80%)	-	-	1 (0.19%)		2 (3.8%)
Ramasamy SK & Ramasamy C [21]. (2019)	50	41 (82%)	6 (12%)	-	2 (4%)	1 (2%)	-	-	-
Present study	105	92 (87.62%)	6 (5.71%)	-	4 (3.81%)	3 (2.86%)	-	-	-

According to Gray, most common variation in branching pattern of arch of aorta is aortic arch with two branches i.e. common trunk of brachiocephalic and left common carotid artery and left subclavian artery [1]. It is also called as 'Bovine arch [22, 23] and its incidence was 10-22% in previous studies [23-25]. Present study observed this bovine arch type pattern in 6 % and this is at a lower side as compared to previous studies [12, 16, 19 -21].

Embryologically, the proximal portion of the left third aortic arch (future left common carotid artery) normally gets absorbed into left horn of the aortic sac which is forming part of arch of aorta. If it gets absorbed in right horn of aortic sac which is forming brachiocephalic trunk, then this variation of common trunk of brachiocephalic and left common carotid artery may formed [4].

In case of bovine arch variation, carotid stenting through femoral approach may become difficult and risky due to firm turn at brachiocephalic and left common carotid artery [26]. According to Malone et al. bovine arch may lead to aortic diseases like aneurysm, dissection because of increased blood flow and increased velocity of blood in the aorta due to reduced opening in the aorta [27]. The accidental occlusion of this common trunk may lead to ischaemic complications because it hampers the blood supply to both common carotids as well as right subclavian and vertebral arteries [28].

Present study observed common trunk of brachiocephalic and left common carotid artery in 9 specimens, out of that, 6 specimens showed only two branches of arch of aorta i.e. common trunk (Brachiocephalic trunk and left common carotid) and left subclavian artery, but in remaining three along with these two branches, left vertebral artery was arising from arch of aorta instead of arising from left subclavian artery thus three branches from arch of aorta. The vertebral artery arose from arch in-between the left common carotid and left subclavian artery in two cases (fig. 6 & 7) and distal to left subclavian artery (Fig 8) in one case.

The origin of left vertebral artery from arch of aorta is common and its incidence is between 2.5 and 8% [25, 29]. Present study observed this variation in 7 cadavers (6.67%). The most common pattern is origin of left vertebral artery in-between left common carotid and left subclavian artery. The anomalous origin of vertebral artery mostly occurs on one side, usually on the left [15, 30]. Manjappa and Gowd in one case observed the variation of common stem of left vertebral and left subclavian artery [19]. Yoruk MD et al. observed the anomalous origin of left vertebral artery in the form of common trunk of left vertebral and left subclavian artery [31]. Hadimani GA et al observed bilateral variation of vertebral arteries. The left vertebral artery directly arises from arch of aorta and right vertebral artery arises from brachiocephalic trunk. Here brachiocephalic trunk ends by trifurcating into right subclavian artery, right vertebral and right common carotid artery [32]. Satti et al during angiography observed origin of left vertebral artery by two limbs. First limb from arch of aorta between left common carotid and left subclavian artery and second limb from left subclavian artery. They mentioned that anomalous origin of vertebral artery may lead to altered haemodynamic which may predispose to intracranial aneurysm. So, in patients with such anomalies thorough search for coexisting aneurysm should be done before clinical condition of subarachnoid haemorrhage so as to decrease mortality [33].

Embryologically, the vertebral artery is formed by formation of post-costal longitudinal anastomosis of adjacent cervical intersegmental arteries and obliteration of the stems of upper six cervical intersegmental arteries and appears as dorsal division of 7th cervical intersegmental artery [34].

In present study, anomalous origin of left vertebral artery from arch of aorta might be due to persistence of left 6th dorsal intersegmental artery which permits the flow of blood from arch of aorta and automatically decreased blood flow through 7th left dorsal intersegmental artery.

In variation of left vertebral artery arising from arch of aorta, there is more susceptibility of left vertebral artery dissection than normal origin from subclavian artery due to its longer course [35].

Several other variations of branching pattern were also previously mentioned. Sometimes double aortic arch may be present and is due to persistent portion of right dorsal aorta between the origin of right 7th intersegmental artery and junction of right and left dorsal aorta. In this variation, a vascular ring is formed which surrounds the esophagus and trachea resulting difficulties in swallowing and breathing [36].

Tapia GP et al. by CT scan observed Left aortic arch in 3 cases. They also observed left aortic arch with right common carotid, left common carotid, left subclavian artery and aberrant right subclavian artery [20]. In such variations right subclavian artery is the final branch of arch of aorta. Embryologically, in such cases the formation of right subclavian is of distal part of right dorsal aorta and right 7th intersegmental artery with obliteration of proximal part of right dorsal aorta and right 4th arch artery. During development there is shortening of aorta between left common carotid and left subclavian artery, finally the origin of right subclavian artery is just below the left subclavian artery. The right subclavian artery to reach the right arm, passes behind the esophagus. which may further cause difficulty in swallowing and respiration [33].

In two cases, they observed right aortic arch[20]. In such cases, left 4th aortic arch and left dorsal aorta were completely obliterated and replaced by right side corresponding vessels [36].

SUMMARY AND CONCLUSION

In present study out of 105 specimens, the normal branching pattern of arch of aorta was in 92(87.62%) and variations in13 (12.38%). Two branches with bovine arch and left subclavian artery was in 6 specimens. Three branches with bovine arch, left vertebral artery, and left subclavian artery was in 3 specimens and four branches with anomalous origin of left vertebral artery from arch of aorta was observed in 4 specimens. The precise knowledge of variations in branching pattern can help the surgeons for performing the appropriate and safe surgical procedures which can minimize the complications during surgeries.

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