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Original Article

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Variations in the branching pattern of aortic arch in human fetal heart: A Morphological Study

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Abstract

***Background & Aims*:** Anatomical variations in the branching pattern of arch of aorta are significant for diagnostic, surgical, and interventional procedures of the thorax and neck, and failure to recognize these patterns may have fatal outcome. Hence the present study aims to determine the percentage and type of aortic arch variations.

Materials & Methods: This cross-sectional study was conducted on 30 formalin-fixed stillborn human fetuses of 35 weeks gestational age and above, in the Department of Anatomy, RIMS, Imphal, Manipur from 2018 to 2020. stillborn human fetuses were collected from the Obstetrics and Gynecology Department of RIMS, Imphal, Manipur, after taking due consent from parent. Fetus with gross abnormality and weighing less than 2.5 kg were excluded. whereas above 2.5 kg weight fetuses were included. The variations in the branching pattern of aortic arch were observed, noted and photographed. The variations were according to the classification by vicurevic et al., 2012.

Results: The classical pattern of three branches of the arch of aorta were seen in 23 (76.66%) cases in the present study. In the remaining 7 (23.33%) cases, two different types of variations were observed with four and two branches arising in five and two cases respectively.

Conclusion: Knowledge of normal anatomy and frequency in the variations in the branching pattern of the arch of aorta in the present study can be of significance for clinicians.

***Keywords*:** Aortic Arch, Brachiocephalic Trunk, Left Common Carotid Artery, Left Subclavian Artery, Left Vertebral Artery

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Introduction

The ascending aorta continues forward as the aortic arch (AA). The aortic arch gives rise to three main branches (1). These are, from left to right, the brachiocephalic trunk (BCT), the left common carotid artery (LCCA) and the left subclavian artery (LSCA). The aortic arch (AA) gives rise to three main branches (1). These are, from left to right, the brachiocephalic trunk (BCT), the left common carotid artery (LCCA) and the left subclavian artery (LSCA). The ascending aorta continues forward as the aortic arch. The origin of the arch, slightly to the right, is in level with the upper border of the second right sternocostal joint. The arch first ascends diagonally back and to the left over the anterior surface of the trachea, then back across its left side and finally descends left of the fourth thoracic vertebral body, continuing as the descending thoracic aorta. Its end is in level with the sternal end of the second, left costal cartilage (2).

The arch, beginning outside the pericardial sac, crosses the trachea anteriorly, giving off the brachiocephalic trunk (innominate artery). This first branch from the arch is normally followed in quick succession by the origins of the left common carotid and left subclavian arteries, also arising from the convexity of the arch (3).

During the eighth week, the primordial pharyngeal arch arterial pattern is transformed into the final fetal arterial arrangement. The left fourth pharyngeal arch artery forms part of the arch of the aorta. The proximal part of the artery develops from the aorta sac and the distal part is derived from the left dorsal aorta. Proximal parts of the third pair of arteries form the common carotid arteries, which supply structures in the head. The right fourth pharyngeal arch artery becomes the proximal part of the right subclavian artery. The distal part of the right subclavian artery forms from the right dorsal aorta and right seventh intersegmental artery. The left subclavian artery is not derived from a pharyngeal arch artery; it forms from the left seventh intersegmental artery. The absorption of left dorsal aorta which brings left seventh intersegmental artery close to left common carotid artery (4).

Although normal branching pattern is present in 63.5–89.4% of individuals, several variations of the branching pattern have been documented in the literature (5). Anatomical variations in the branching pattern of aortic arch are significant for diagnostic, surgical, interventional procedures of the thorax and neck and failure to recognize these patterns may have fatal outcome (6). The anomalous branching pattern of the aortic arch can alter the cerebral hemodynamics, which in turn can lead to cerebral abnormalities. Therefore, clinicians and surgeons should be aware of aortic arch variations and prior identification of these vascular anomalies through diagnostic interventions is crucial in order to avoid complications during heart and vascular surgeries (7).

Hence the present study aims to determine the percentage and type of aortic arch variations in formalin fixed fetuses.

Materials & Methods

The present descriptive cross-sectional study was conducted on 30 formalin-fixed full-term human fetuses in the Department of Anatomy, Regional Institute of Medical Sciences, Imphal, Manipur, India during the years 2018 - 2020. The ethical committee approval and the written consent from the family members of the fetuses were also obtained. Stillborn human fetuses were collected from the Obstetrics and Gynecology Department of Regional Institute of Medical Sciences, after taking written consent on the due consent form from parent. Study sample size is calculated based on the prevalence of branching of arch of aorta in a study among American in 2003 year. Fetus with gross abnormality and weighing less than 2.5 kg were excluded whereas above 2.5 kg weight fetuses were included. After skin incision, sternum was cut transversely at the manubrio-sternal joint. 1st and 2nd ribs were cut on both sides and manubrio-clavicular joint was disarticulated. Manubrium was removed to visualize superior mediastinum. Then fats were cleaned and structures in the superior mediastinum were observed. The variations in the branching pattern of aortic arch were noted and photographed.

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The variations were then grouped according to the classification of Kumar A et al. in 2015 (6) based on Vicurevic et al., (2012) method as follows:

Type A = Brachiocephalic trunk (BCT), left common carotid artery (LCCA), left subclavian artery (LSA) (3 Branches),

Type B = Brachiocephalic trunk, left common carotid artery, left vertebral artery (LVA) and left subclavian artery (4 Branches),

Type C = Common trunk (BCT and LCCA), LSA (2 branches),

and Type D = Right Subclavian artery (RSA), left Subclavian artery, right common carotid artery (RCCA) and left common carotid artery, directly from arch (4 Branches).

Results

Twenty-three (76.66%) of the aortic arches showed the classical branching pattern of three branches, the brachiocephalic trunk, left common carotid and left subclavian arteries, Type A (Table 1). In the remaining 7 (23.33%), four and two branches were arising out of aortic arch. In five cases (16.66%) four branches were seen, Type B, but in this too, two different types of branching patterns were noted (Table 1).

Table 1. Types of aortic arch variations in the present study

Types of presentation	Number and description of the branches	Frequency	Percentage
Type - A	3 Branches- BCT, LCCA & LSA	23	76.66
Type - B	4 Branches BCT (RSA, RCCA), LCCA, LVA & LSA	3	16.66
	BCT (RSA, RVA, RCCA), LCCA, LVA & LSA	2	
		5	
Type -C	2 Branches -CT & LSA	2	6.66
Type - D	4 Branches-RSA, RCCA, LCCA & LSA	0	-
Total		30	100

BCT - brachiocephalic trunk
LCCA - left common carotid artery
LSA - left subclavian artery
RSA - right Subclavian artery
RCCA - right common carotid artery
LVA - left vertebral artery
RVA - right vertebral artery
CT - common trunk

The commonest pattern was that the four branches in three cases were the brachiocephalic trunk, left common carotid artery, left vertebral artery and left subclavian artery (Tables 2 and 3).

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Table 2. Proportion of variant branching of aortic arch in different populations

Author	Population	Number	Proportion of aortic arch with variant branching (%)
Gielecki JS et al. (8) (2004)	Polish	103	27.2
Grande NR et al. (9) (1995)	Portuguese	33	18
Natsis KI et al. (10) (2009)	Greek	633	17
Nelson ML et al. (11) (2001)	Japanese	193	5.7
Satyapal KS et al. (12) (2003)	South African	320	5.3
Shin Y et al. (13) (2008)	Korean	25	16
Ogenh'o et al. (14) (2010)	Kenya	113	32.7
Moskowitz WB et al. (15) 2003	American	1480	3.2
Current study (2020)	India	30	23.33

Table 3. Incidence of arch of aorta with two branches – A common trunk of brachiocephalic and left common carotid artery and left subclavian artery in different populations

Author	Population	Number of specimens	Percentage
Lale P et al. (16) (2014)	Turkey	881	7.2
Pandian DK et al. (17) (2014)	Indian	30	33.33
Mata-Escolano F et al. (18) (2012)	Spain	900	5.11
Ogenh'o JA et al. (14) (2010)	Kenya	113	25.7
Kumar A (6) (2015)	Nepal	42	2.38
Makhanya NZ et al. (19) (2004)	Southern Africa	60	28.3
Natsis KI et al. (10) (2009)	Greece	633	15.16
Budhiraja V et al. (20) (2013)	Central India	52	19.2%
Nelson ML and sparks (11) (2001)	Japanese	193	1
Current study (2020)	India	30	6.66

The left vertebral artery was seen arising directly from aortic arch in between the LCCA and LSA. The other pattern was seen in two cases where the branches were brachiocephalic trunk, LCCA, LVA and LSA but the BCT was trifurcating to give arise to three branches namely RSA, RVA (right vertebral artery), RCCA. The right vertebral artery was seen arising in between the junction of the right common carotid artery and right subclavian artery in the above two cases (Table 2). The second variation seen was of two branches arising from the arch of aorta in 2 cases (6.66%), Type C, namely common trunk and left subclavian artery (Table 4). The common trunk was giving rise to BCT and LCCA.

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Table 4. Incidence left vertebral artery from the aortic arch

Type of presentation	Sample size	Normal	Common trunk	Lt. vertebral artery from arch of aorta
Budhiraja V et al. (20) (2013)	52	63.5(33)	19.2(10)	15.3(8)
Nayak SR et al. (21) (2006)	62	90.32(56)	4.8(3)	1.61(1)
Lale P et al. (16) (2014)	881	87.4(770)	7.2(64)	2.8(25)
Pandian DK et al. (17) (2014)	30	63.33(19)	33.33(10)	3.33(1)
Mata-Escolano F et al. (18) (2012)	900	81.55(734)	5.11(46)	1.77(16)
Ramasamy SK et al. (22) (2019)	50	82(41)	12(6)	6(3)
Sawant SP et al. (23) (2017)	50	94(47)	-	6(3)
Ogenh'o JA et al. (14) (2010)	113	67.3(76)	25.7(29)	3.5(4)
Current study (2020)	30	76.66(23)	6.66(2)	16.66(5)

Discussion

In the present study, the normal branching pattern of the aortic arch was observed in 23 (76.66%) cases and in 7 (23.33%) of cases, the aortic arch showed variations. The findings of this study were then compared with other studies by various authors in India and in other countries to know the presence of any geographical differences.

The normal three-branch pattern of the aortic arch is found with an incidence of 64.9-94.3% according to the literature (23), which is consistent with the findings of the present study. Variations of the branching pattern of aortic arch observed in this study is less as compared to the findings of Gielecki JS et al. (8) and Ogeng'o JA et al. (14). Ogeng'o JA et al. also reported that deviation from conventional branching pattern occurs more commonly in the Kenyan population (14). These findings of higher occurrence may be due to racial and geographical differences.

In the present study, the most common variations of the branching of the arch of aorta were 4 branches, namely BCT, LCCA, LVA, and LSA, which was seen in 5 (16.6%) cases. This finding differs from the findings of Ogeng'o JA et al. (14), Lale P et al. (16), Pandian DK et al. (17), Budhiraja V et al. (20) and Ramasamy SK et al. (22) involving different population groups where they reported the most common variations were 2 branches arising from aortic arch.

Previous studies describing two branch patterns in different population groups ranges from 1% to 33% as shown in Table 3. In our study, 2 branches pattern from aortic arch as the second common variation seen in only 2 (6.6%) cases.

The 4-branch pattern from arch of aorta namely BCT, LCCA, LVA, LSA is also reported by previous authors in studies of different population groups. The left vertebral artery arising directly from the aortic arch was seen in 5 (16.6%) cases in the present study, which is a higher occurrence than previously reported. Budhiraja V et al. (20) reported 8 (15.3%) cases of left vertebral artery from the arch of aorta which is close to the findings of our study whereas Nayak SR et al. reported the least incidence of 1 (1.61%) (21).

In our present study, out of the 5 cases of 4 branch pattern from the arch of aorta, 2 cases also presented with BCT trifurcating into RSA, RVA, RCCA (from right to left). The right vertebral artery (RVA) is seen arising between RCCA and RSA in the present study. This finding is similar with the findings of Shiva Kumar GL et al. (7). According to Sikka A et al. (24) the right

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vertebral artery may arise (a) from the first part of subclavian nearer than normal to the brachiocephalic (1% of cases) or to the anterior scalene muscle, (b) directly from the aortic arch (3% of cases), (c) from the right common carotid, when the right subclavian arises from the aorta beyond the left subclavian or (d) from the brachiocephalic trunk. In the present study, the right vertebral artery (RVA) is seen arising directly from the BCT between RCCA and RSA. These variations arise from defects during development which may be due to (i) the choice of unusual paths in the primitive vascular plexus, (ii) the persistence of vessels normally obliterated, (iii) the disappearance of vessels normally retained, (iv) incomplete development, and (v) fusions and absorption of the parts usually distinct (7, 14, 22, 23). A common brachiocephalic trunk may be a variant of aortic arch development in which both common carotid arteries and the right subclavian artery originates from a single trunk that arises from the arch (7). A left vertebral artery of aortic origin in the present study may be because of the persistence of the dorsal division of the left 6th intersegmental as the first part of the vertebral artery instead of that of the left 7th intersegmental artery. Understanding the variability of the vertebral artery is most important in angiography and surgical procedures where an incomplete knowledge of anatomy can lead to serious implications (24).

Conclusion

Knowledge of normal anatomy and frequency in the variations in the branching pattern of the aortic arch in the present study can be of significance for clinicians in the head, neck and thoracic region. Especially, it's most important in angiography and surgical procedures where an incomplete knowledge of anatomy can lead to serious implications. We recommended to use imaging to get a better understanding, as well as higher sample size to get more reliable results in the future studies. The limitation of the present study was a low sample size, the different ethnic backgrounds of the fetuses and a dissection-based study.

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Ethical statement

Ethical approval code of the study is "vide A/206/REB-Comm(SP)/RIMS/2015/533/11/2019"

Data availability

The raw data supporting the conclusions of this article are available from the authors upon reasonable request.

Conflict of interest

The authors have no conflict of interest in this study.

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