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Anatomical Variation in Branching Pattern of Aortic Arch and Number of Pulmonary Veins – A Cadaveric Case Report

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Abstract

The heart, a hollow muscular organ, consisting of four chambers; right atrium, right ventricle, left atrium and left ventricle; along with the major blood vessels namely, superior and inferior vena cava, pulmonary arteries, pulmonary veins and aorta, bring and take blood from these chambers, ensuring proper pulmonary and systemic circulation of blood in the body. Normally the oxygen-poor venous blood, after being oxygenated in the lungs, flows back to the left atrium via four pulmonary veins while oxygen-rich blood enters the systemic circulation, especially the region of head and neck via the three branches of the aortic arch.

However, variations of the branches of aortic arch and pulmonary veins are often observed perhaps due to alteration in the development of certain branchial arch structures during embryonic period. Here we present a unique case of anatomical variation in branching pattern of aortic arch and number of pulmonary veins draining into the left atrium; both variations found in a single heart of an elderly male cadaver during the routine dissection of the heart for medical students. Knowledge of the normal anatomy and the variations of these key structures is crucial for apt clinical evaluation and life-saving surgical and interventional procedures such as aortic instrumentation or thoracic and neck surgeries.

Keywords: Vertebral artery, aortic arch, pulmonary veins, variations

Introduction

The arch of aorta (AA) gives three classical branches, namely the brachiocephalic trunk (BCT), the left common carotid artery (LCCA), and the left subclavian artery (LSA).

These branches may originate from the commencement of the arch or from the upper border of the ascending aorta by varying distances between them. The BCT bifurcates into the right common carotid artery (RCCA) and the right subclavian artery (RSA) [1].

Variations in the branching pattern of aortic arch are common in terms of number because of the complex developmental process [2]. Awareness and the comprehensive knowledge of abnormal branches originating from aortic arch is important in diagnosis of cerebral hemodynamic disorders and intracranial aneurysm [3].

Pulmonary veins (PV) carry oxygenated blood from the lungs to the left atrium (LA) of the heart. The variations with respect to the number and drainage pattern of PV is frequent and this knowledge is valuable for various procedures like in cardio-thoracic surgeries, radiological procedures such as radiofrequency ablations in atrial fibrillation, cardiac valve replacements, pulmonary lobectomy [4].

Case Report

During routine dissection of the thorax region of a male cadaver which was donated under the body donation program, as part of the teaching program for Year I MBBS students, in the Department of Anatomy, JSS Medical College, we report a case of variation in the branches arising from arch of aorta and number of PV. The sternum was turned on to the upper part of the abdominal wall. The lungs were removed, superior vena cava and brachiocephalic veins cleared, and pericardium opened to expose ascending aorta. The fat tissue and the pericardium covering the ascending aorta and the great vessels were removed to visualise the branches of aortic arch. In this case, aortic arch showed four branches; the fourth being the left vertebral artery (LVA), was arising from aortic arch between LCCA and LSA; as seen in Figure 1.

The right and left brachiocephalic veins were gently cut. The number of right PV and left PV were seen, close to the heart, from the external aspect. LA was opened by giving a midline incision along the whole length of its posterior wall, to study the drainage pattern of PV. In the present case, PV were three in number on both the sides with two ostia, one extra vein was smaller in calibre than the other; as seen in Figure 2.

Images:

Figure 1: Showing the aortic arch with four branches and the left vertebral artery arising from aortic arch between left common carotid and left subclavian artery

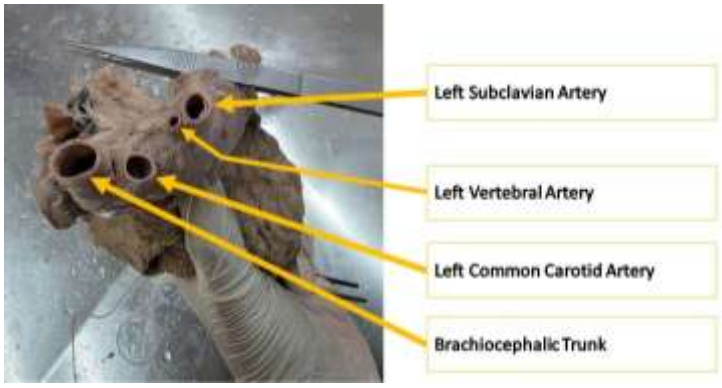

Figure 2: Showing the three pulmonary veins on both the sides with two ostia and one extra vein, smaller in calibre than the other

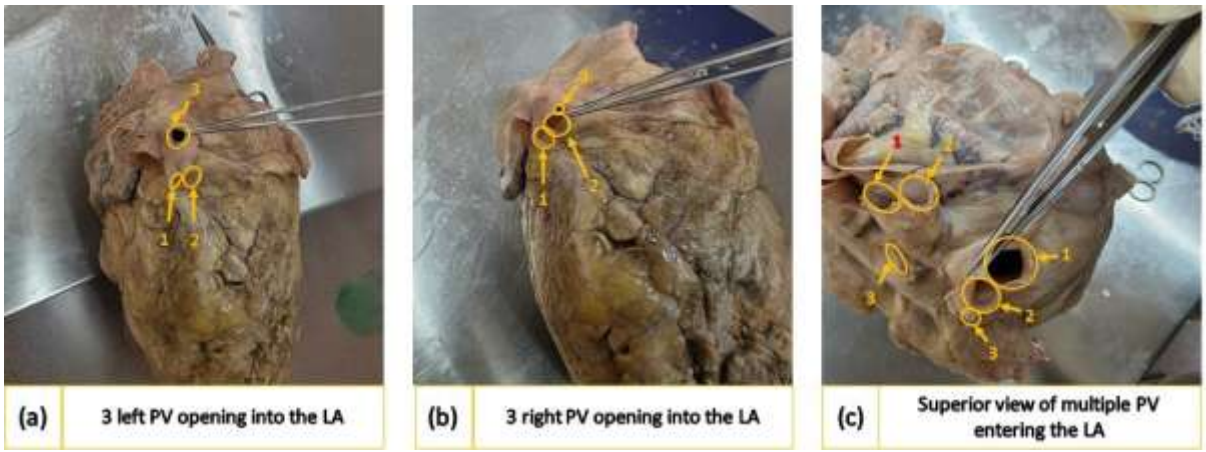

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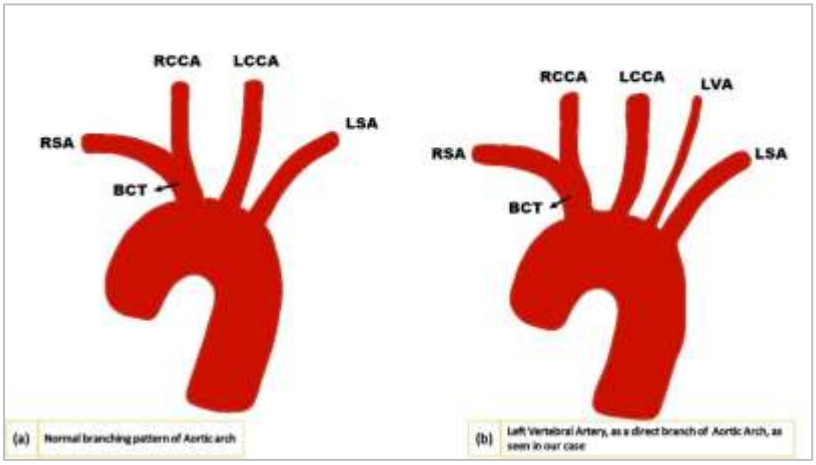
Figure 3: Schematic diagram showing the normal branching of Aortic arch and Left Vertebral artery as a direct branch of Aortic arch



Discussion

The heart, a cone-shaped hollow muscular organ, consisting of four chambers; is involved in pulmonary and systemic circulation. The aorta and arch of aorta carry oxygen-rich blood from the left ventricle to the body, while oxygen-rich blood returns from the lungs to the LA via the PV. [5,6]

The aortic arch (AA), a continuation of the aorta from the left ventricle, situated in the superior mediastinum, is said to have three branches; the BCT, LCCA, and LSA that emerge from the AA in about 65–80% of cases. [7]. Variants with respect to AA's branching pattern are the number of branches arising from arch of aorta and the distance between the sources of these branches [8]. Various factors are responsible for the variants such as varying rates of growth in the respective arteries and in some cases chromosome 22q11 deletion is also associated with the AA anomalies. [9]

Certain variant aortic branches, such as the left vertebral artery (LVA) as found in our case, are challenging to identify pre-op because they are frequently hidden by other, larger arch branches. Since they are typically found intra-operatively, more care must be employed when the arch branches are being dissected and made visible.

Budhiraja V et al reported a significantly higher percent of variation (36.5%) in branching pattern compared to the statistics in previous literatures as seen in Table 1, with the four-branch pattern of AA branching as seen in our case, also being higher compared to previous studies as seen in Table 1. Developmentally, the proximal portion of the seventh cervical segmental artery's dorsal branch, proximal to the postcostal anastomosis, forms the first segment of the LVA and the second part from the longitudinal communications of the post costal anastomosis. [7]

The aberrant origin of LVA, as seen in our case, may be due to the persistence of the left sixth segmental artery or greater absorption of LSA embryonic tissue between the vertebral artery origins and the aortic arch, or potentially the persistence of the 8th intersegmental artery [10][11] as suggested by Albayram et al. [12]

Atherosclerosis most often seen in the prevertebral segment of LVA of aortic origin leading to cerebral hemodynamic changes and cerebral disorders are due to abnormal vertebral artery origin.[13] Other reports note similar LVA variations arising from the AA, while some studies report the right vertebral artery branching directly from the AA. [14, 15, 16, 17]

In the year 2009, Natsis et al., classified variations as Type I– VIII [18] but later in the year 2018 Popieluszko et al., identifies seven major types without a Type VIII, and based on their meta-analysis of 23,882 adult aortic arches from 51 studies, the most common branching pattern was an aortic arch (from right to left), which gives off the BCT, the LCCA and the LSA with an overall incidence of 80.9%. The second most common pattern was the bovine arch variant in 13.6%, followed by the LVA variant in 2.8%. In the present case, LVA taking its origin

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directly from aortic arch is of Type III according to Popieluszko's Classification. (as seen in Table 2) [19]

During the decompression of the cervical spine, type 3 variant needs extra caution as injury to the vertebral arteries is a common complication [18]. It is also noted that type III variants are more prone to certain pathologic processes and surgical complications. In general, no symptoms are observed in patients with this variant on a day-to-day basis, but it may cause complications during surgical procedures. The patients with the LVA variant may have an increased risk of vertebral artery dissection compared with patients without the variant because of the LVA having a longer course [19].

Therefore, considering all these variations, surgeons must be aware of these variations in large vessels since even a small, unforeseen damage to the vessels can result in an unexpected, substantial bleeding.

Regarding pulmonary veins, typically four (right/left; superior and inferior PVs) enter the posterior wall of the LA. Variations in PV structure are frequently associated with an increased risk of arrhythmia and atrial fibrillation pathogenesis. [20]

Atrial fibrillation is commonly managed with radiofrequency ablation techniques and an understanding of the number and location of PV with left atrial wall thickness is vital for this electrophysiological technique. [21] To understand the anatomical variations of the PV in the LA, knowledge of its embryological development is important.

The right and left PV are the branches from the main PV and each branch further divides into upper and lower branches. The dorsal wall of the LA is formed by the incorporation of four PV into the atrium. [22] Supernumerary or accessory PVs, usually found on the right side, result from the incorporation of PVs beyond their first division. [23]

In the present case, PV were three in number on both the sides with two ostia, one extra vein was smaller in calibre than the other.

When the upper and lower veins on the same side merge, it results in the conjoined vein and a single ostium is formed; this is commonly seen on the left side. [24] Alsaif et all reported that 3-5 ostia were noted on the right side in about 16% of samples and single ostia on the left side in about 2.67% of hearts. [8] and Marom et al, in their study reported 14% had single ostium. [25].

The variations in the number of PV opening into the LA may have an influence on initiating ectopic atrial electrical activity. Identifying PV anomalies are an important factor that helps the surgeons approach toward the therapeutic intervention. The study also emphasizes on pre-procedural imaging of the LA and PV before performing any interventional endoscopic procedures.

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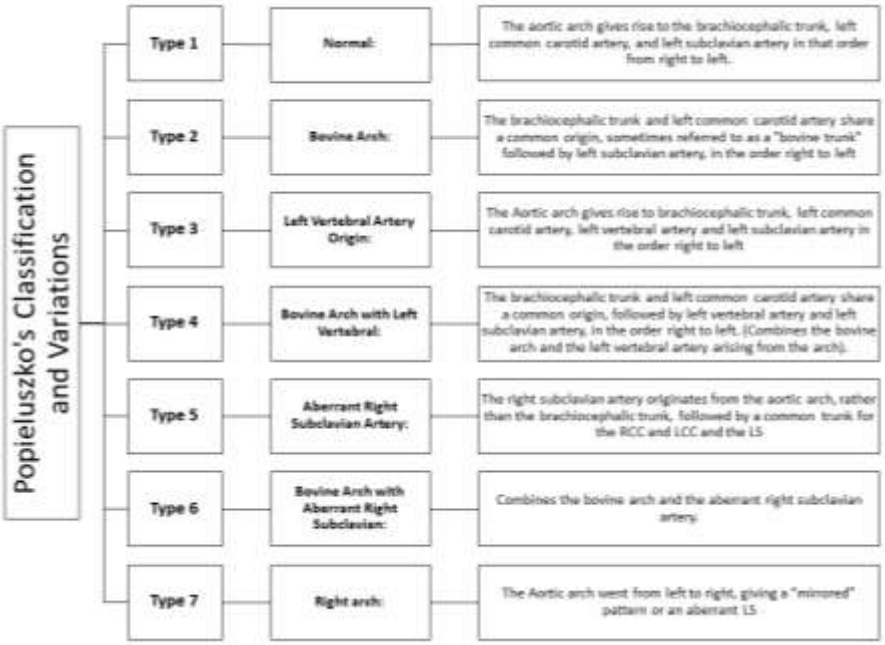
Tables

Table 1: Percentage of Aortic arch with variant branch pattern.

Author's name	Population	Percentage of aortic arch with variant branch pattern	Percentage of four branches pattern (BCT, LCCA, LVA, LSA)
Grande et al. (1995)	Portuguese	18.0	-
Matula et al. (1997)	Austrian	-	3.0
Voster et al. (1998)	South African	-	5.0
Nelson and Sparks (2001)	Japanese	5.7	4.1
Satyapal et al. (2003)	South African	5.3	-
Gielecki et al. (2004)	Polish	27.2	6.8
Makhanya et al. (2004)	South African	-	1.7
Bhatia et al. (2004)	Australian	-	7.4
Shin et al. (2008)	Korean	16.0	8.1
Natsis et al. (2009)	Greek	17.0	-
Bhattarai and Poudel (2010)	Nepalese	-	7.0
Ogeng'o et al. (2010)	Kenyan	32.7	-
Budhiraja V et al. (2013)	Indian	36.5	15.3

Table 2: Popieluszko's Classification



Conclusion

This rare instance of a single heart with variations of LVA branching directly from the AA and the number of PV, emphasizes why understanding the distinct branching pattern of AA is crucial for aortic instrumentation, thoracic & neck procedures, elective & emergency surgeries in the superior mediastinum; as well as for the diagnosis of a number of clinical disorders.

On the other hand, the variation in PV may impact the LA's hemodynamic and result in pathologies like atrial fibrillation. For the purpose of accurately diagnosing cardiovascular conditions as well as planning and carrying out interventions, it is crucial to understand

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the normal structure and the clinical variations that are frequently observed.

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