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A rare variant of aortic arch branching — case report

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ABSTRACT

During the dissection of an 82-year-old male specimen, we found an atypical variant of the aortic arch with 5 branches instead of the usual 3. The additional arteries were identified as the IMA thyroid artery (the artery of Neubauer) and the left vertebral artery, which arose directly from the aortic arch. The IMA artery was located between the origin of the brachiocephalic trunk and the left common carotid artery. The left vertebral artery was situated between the origin of the left common carotid artery and the left subclavian artery. No other variations in the origins of major vessels in the thoracic region, head, and neck were observed. The frequency of the left vertebral artery arising directly from the aortic arch is estimated to be 3–8%, and when combined with the IMA artery arising directly from the aortic arch, which occurs in less than 1% of cases, the variant described appears to be extremely rare. In this paper, we present the exact measurements of the arteries we found, their topography relative to other significant anatomical structures, and the potential clinical significance of these variations. The work is accompanied by diagrams and photographs.

Keywords: aortic arch, IMA thyroid artery, left vertebral artery

INTRODUCTION

The embryonic development of the aorta begins with the divided of the truncus arteriosus by the aorticopulmonary septum, which leads to the formation of the primitive aorta. This primitive aorta gives the ventral aortae, brachial arches, and dorsal aortae. The ventral aortae contribute to the development of the brachiocephalic trunk, the right external carotid artery, and the ascending aorta. The descending aorta, vertebral arteries, superior intercostal arteries, and deep cervical arteries originate from the dorsal aortae. The third, fourth, and sixth brachial arches contribute to the formation of aortic arch (AA), the ductus arteriosus, the internal carotid arteries, the subclavian arteries, and the pulmonary arteries [9]. The AA is located in the upper mediastinum. It connects the ascending aorta with the descending aorta (thoracic part). In 65–80% of cases, the AA has a standard structure, consisting of three branches. In the most common variant, these branches are, from right to left: the brachiocephalic trunk, the left common carotid artery (LCCA), and the left subclavian artery. Variations in the structure of the AA mainly involve its position, course, the origin of its branches, and their number. The most common variations concern the distance between the arterial trunks arising from the AA and their dimensions. Changes in the number of vessels arising from the AA are rarer [1]. Common AA variants include one to as many as six vessels arising directly from the AA [8]. The most frequent of these variants is the pattern containing a common trunk for the right subclavian artery, the LCCA, and the right common carotid artery, forming a pattern with 2 branches of the AA. The second most common variant in terms of the number of AA branches is the presence of the left vertebral artery (LVA) arising directly from the aortic arch, forming a pattern with four branches. However, any pattern of the AA containing a common arterial trunk forming a three-branch arch pattern, as well as all patterns containing five or more branches, are extremely rare [8, 13, 23]. In most cases, variations in the aortic arch do not affect the patient’s life or functioning. However, in rare instances, they can cause clinical symptoms. One such variant is the presence of the aberrant right subclavian artery, also known as lusoria artery, which position exerts pressure on the esophagus, which manifests as dysphagia, but in a smaller percentage of cases, a retrotracheal course of lusoria artery can exert pressure on the trachea causing dyspnea [7, 13, 16]. Various AA variants can also have a significant impact on the planning and success of vascular surgery procedures in the heart, head and neck, and upper limbs, thoracic surgery, as well as emergency medical procedures performed in the head and neck region [11, 14]. In order

to ensure the clarity of the case report presented herein, we have endeavored to adhere to the guidelines set forth in the work by Wysiadecki G. et al. [24]. The standardization of content presentation in case report articles allows for better comprehension by the reader, as well as facilitating the preparation of review articles and meta-analyses.

CASE REPORT

During a routine anatomical dissection of an 82-year-old male, we observed a variation in the aortic arch in the form of five arterial trunks arising directly from this part of the main artery. The variation consisted of two additional vessels. The smaller vessel, with a diameter of 2.34 mm and a length of 84.7 mm, arose between the brachiocephalic trunk and the LCCA, ascending toward the thyroid gland and entering the gland's tissue from its inferior side. The larger vessel, with a diameter of 4.26 mm and a length of 93.14 mm, arose between the LCCA and the left subclavian artery, ascending straight upward, crossing behind the left brachiocephalic vein, and then entering the transverse foramen of the cervical vertebrae at the level of 6^{th} cervical vertebrae (C6). Based on the course of these vessels and available literature, the vessels were identified as the thyroid ima artery and the LVA, respectively. The remaining vessels, such as the brachiocephalic trunk, right subclavian artery, right common carotid artery, right vertebral artery, and left subclavian artery, follow a normal course and do not exhibit any changes in their position, consistent with normal anatomical literature. Similarly, the remaining arteries supplying the thyroid gland, namely the superior thyroid artery and inferior thyroid artery, do not show any changes in their course or number, arising from the external carotid arteries (superior thyroid arteries) and subclavian arteries via the thyrocervical trunks (inferior thyroid arteries). The diameters of all the mentioned arteries, as well as the diameters of the main aorta and aortic arch, were measured with calipers at the widest points of their course. Before the measurements were taken, it was ensured that the condition of the measured structures allowed for minimizing measurement error (avoiding bending, flattening, or unnatural stretching of the arteries). Measurements were taken twice by two independent researchers (GZ and JW), after which the average value was calculated from all the measurements. All measurements were placed in Table 1. Figure 1 presents the described variation. Figures 2 and 3 show images of anatomical specimens with the five branches of the aortic arch dissected by us.

DISCUSSION

Classifications of AA variants exhibit significant diversity. They are influenced by factors such as the number of AAs examined and variations in aortic arch morphology within the studied population. G. Vučurević et al. [23] and Natsis et al. [15] investigated 1266 and 633 AAs, respectively, and categorized them into seven different variants. Abnormal LVA origin was observed in 46 cases in the study by G. Vučurević et al. [23] and was classified as variants VIa, VIb, and VIc, while TIA was observed in 28 AAs as variant VIII. In contrast, in the study by Natsis et al., LVA originating from the AA was present in 5 cases as variant III, and TIA in 1 case as variant VIII [15, 23]. Liechty et al. [8] examined 1000 human cadavers and identified fourteen different AA variants. In this study, abnormal LVA origin was observed in five variants — III, IV, V, XII and in XIV. Accounting for 41 cases, while TIA was detected in 6 AAs and classified as variant XII. In a large meta-analysis by Popieluszko et al. [18], 51 articles from various regions of the world were analysed, comprising a total of 23,882 aortic arches. These were divided into 7 categories, of which the most frequent variant was the normal one with three branches, in the following order: brachiocephalic trunk, LCCA, and left subclavian artery, occurring with a frequency of 80.9%. The second most common variant, with a frequency of 13.6%, consisted of two branches: a common trunk for the brachiocephalic trunk and LCCA, and the left subclavian artery. An additional left vertebral artery, present in the third variant and resulting in an aortic arch with four branches, was observed in 2.9% of cases. Additionally, the authors noted differences in the occurrence of variants depending on the geographical region, with populations from South America and Africa exhibiting a higher frequency of the second type of variant. In contrast, no differences from the accepted model were found in populations from South America, Europe, Asia, and the Middle East [18]. In a review study by Murray and Meguid [12] 28 variants from 24 articles were identified. LVA was observed in 2.4–6.9% of cases, and TIA with a frequency of 0.08–2%. Both Popieluszko et al. and Murray A and Meguid E. A. highlighted the discrepancy in AA variant classifications and because of the important clinical aspect of some of the variations authors emphasized the need for a standardized classification system for AA [12].

The thyroid ima artery was discovered by Johann Ernst Neubauer in 1772 and later named after him [17]. It is an anatomical variation occurring in 4–10% of cases. This artery occurs much more frequently in fetuses — in about 14.8% of cases. This is related to the embryonic origin of the TIA, which, due to the failure of vessel closure during the development

of the thyroid gland between the 4th and 7th week of pregnancy, remains patent in fetal life or, in rarer cases, in adult life [2]. The most common source of the artery is the brachiocephalic trunk (74%), followed by the right common carotid artery (9.6%), the aortic arch (7.7%), the right internal thoracic artery (4.8%), the LCCA (1.9%), and the left internal thoracic artery (1.9%) [27]. In rare cases, the artery is shorter and supplies only the thymus as the arteria thymica accessoria [19]. Clinically, the presence and location of the TIA is very important. Surgical procedures performed in the chest and neck, such as percutaneous tracheostomy, may lead to damage to the TIA and fatal hemorrhage requiring immediate intervention due to its frequent origin from a major arterial vessel [6]. Confirming the presence of the TIA should be a key element in thyroid surgery to avoid hemorrhage and urgent sternotomy [10]. Additionally, blunt chest trauma may result in damage to the TIA and subsequent massive mediastinal hematoma. Endovascular embolization performed during an arteriography procedure allows for the safe management of hemorrhage resulting from TIA damage [25]. Therefore, identifying the TIA before procedures in the neck and mediastinal area using imaging techniques such as computed tomography, magnetic resonance imaging, or arteriography is crucial [4].

The left vertebral artery is a vessel of significant clinical importance due to its role in supplying blood to, among other areas, the posterior part of the brain and the spinal cord. This artery typically arises from the left subclavian artery as its first branch. It then travels upwards, and upon reaching the level of the sixth cervical vertebra (C6), it enters the transverse foramen of the cervical vertebrae. After exiting the foramen, it courses between the first and second cervical vertebrae to the surface of the occipital bone, ultimately joining the contralateral vertebral artery to form the basilar artery, which is an essential part of the cerebral circulation [26]. A variant of the LVA, arising directly from the aortic arch, appears to be the most common variation of the LVA origin, with its occurrence ranging from 3% to as high as 14%, depending on the study [3]. The most frequent location of the LVA arising directly from the aortic arch involves its positioning between the LCCA and the left subclavian artery, which is consistent with the case we observed [20]. Although this variant typically does not affect the daily functioning of patients, its presence significantly increases the difficulty and alters the specificity of vascular procedures performed using endovascular and open techniques [21]. In cases where such patients experience aortic dissection involving the area of the left vertebral artery’s origin, an effective treatment is the transposition of the LVA to the left common carotid artery, combined with a

Thoracic Endovascular Aortic Repair (TEVAR) procedure [17]. Tardieu et al. [22] point out that due to the altered course of the LVA arising directly from the aortic arch (this artery typically runs more medially and enters the transverse foramen at a higher level than the standard C6), there is a potential risk of its injury during anterior cervical spine surgery, which could result in a life-threatening hemorrhage, as well as disrupted perfusion in the vertebrobasilar region, leading to severe neurological complications.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

The donor had provided advanced consent for the use of his body for anatomical teaching and research after death.

Author contributions

Anatomical dissection: GZ, JW. Data collection: GZ, JW, RK. Data analysis: GZ, JW. Manuscript — writing: GZ, JW. Manuscript — editing: RK, TL. Scientific supervision: GB.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Table 1. Average measurement results.

Vessel	Diameter [mm]
Aortic bulb	31.62
Ascending aorta	29.9
Aortic arc	31.77
Descending aorta	27.31
Brachiocephalic trunk	17.75
Right common carotid artery	9.36
Right subclavian artery	16.1
Right vertebral artery	5.41
Thyroid ima artery	2.34
Left common carotid artery	9.41
Left vertebral artery	4.26
Left subclavian artery	9.02
Right superior thyroid artery	4.03
Left superior thyroid artery	4.77
Inferior thyroid artery	5.07

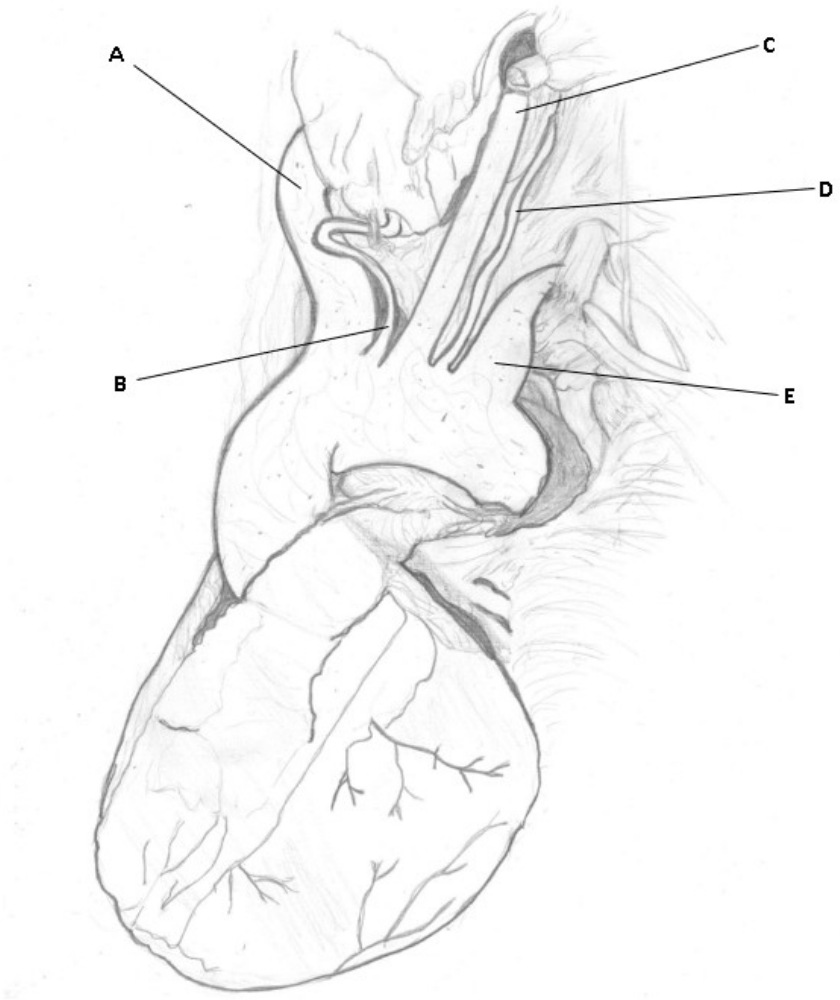

Figure 1. The figure shows the aortic arch with five branches A–E. A — brachiocephalic trunk, B — ima thyroid artery, C — left common carotid artery, D — left vertebral artery, E — left subclavian artery.

Figure 2. The photo shows the aortic arch with five branches A–E. A — brachiocephalic trunk, B — ima thyroid artery, C — left common carotid artery, D — left vertebral artery, E — left subclavian artery.

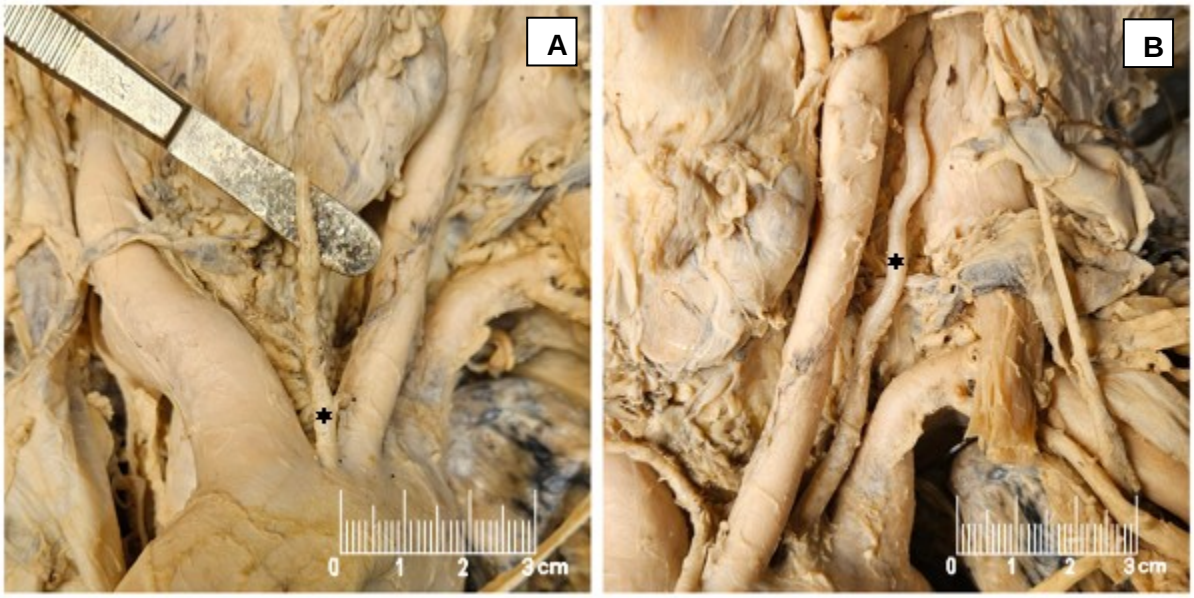

Figure 3. The photos show ima thyroid artery, marked with an "*" (**A**) and the left vertebral arteries, marked with an "*" (**B**).