**ANATOMICAL VARIATIONS OF THE AORTIC ARCH BRANCHING PATTERN**

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**Abstract**

Anatomical variations of the aortic arch and its branches are fairly common and can have important implications on prognosis and management of surgical interventions, as well as on radiological diagnostics and interventional radiology.

The aim of this study was to present the anatomical variations in branching pattern of the aortic arch in a large group of patients using CTA and consequently to determine their prevalence in our population.

The study population included 1000 patients with referral diagnoses requiring CTA chest radiography, which visualizes the aortic arch. The course of the aortic arch was clearly observed in all of the 1000 patients. The anatomic features of the aortic arch itself and supra-aortic vessels were analyzed, and anatomical variations were recorded on each CT image.

The results showed that 89.3% of the cases had the usual branching pattern of the aortic arch. The most common variation was aortic arch with two branches, with left common carotid artery arising from brachiocephalic trunk (7.9%). Separate origin of the left vertebral artery between the left common carotid artery and the left subclavian artery was present in 2.8% of cases.

The knowledge of the anatomy of the aortic arch and its branches and the awareness of vascular variations is an imperative in diagnostic procedures and in planning surgical interventions during clinical practice.

***Keywords:*** aortic arch, variations, anatomy

**Introduction**

The most frequent branching pattern of the aortic arch is its classical anatomical configuration where the arch is left sided, the brachiocephalic trunk (BCT) is the first and the largest vessel arising from the aortic arch, followed by the left common carotid artery (LCCA) and left subclavian artery (LSA). This “normal” arch occurs in 64.9-94.3 of the cases [1-5]. Anatomical variations of the aortic arch and its branches are fairly common and can have important implications on prognosis and management of surgical interventions, as well as on radiological diagnostics and interventional radiology [6-13]. They could be attributed to alteration in the development of the aortic arch system into an adult pattern. This process can be described by persistence or regression of segments of the hypothetical double aortic arch system proposed by Edwards [14]. According to this theoretical model consisting of bilateral arches and arterial duct encircling the trachea and esophagus, the potential contributions of nearly all embryonic arches to components of the definitive adult arch system can be explained. It is possible by postulating regression of a segment that would normally persist, and/ or persistence of a segment that would normally regress [14, 15].

Modern radiological techniques such as computerized tomographic angiography (CTA) and magnetic resonance angiography provide an insight into the state of the aortic arch and allow an individual approach to each patient. CTA is a noninvasive technique that enables rapid and high-spatial-resolution evaluation of vascular anomalies along with assessment of tracheal or esophageal compression. Disadvantages of CT angiography include radiation exposure and a relatively high rate of intravenous contrast medium injection [15, 16].

The aim of this study was to present the anatomical variations in branching pattern of the aortic arch in a large group of patients using CTA and consequently to determine their prevalence in our population.

**Material and methods**

The study population included 1000 patients referred to the University Clinic for Surgical Diseases "St. Naum Ohridski" in Skopje with referral diagnoses requiring CTA chest radiography, which visualizes the aortic arch (arterial diseases and aneurysm of the aorta, traumatic vascular chest injury, pulmonary embolism). The study included patients from both sexes, older than 18 years. The collection of images was made by a specialist radiologist involved in the study.

Before the examination, the patients had been informed that their recordings would be used for the purposes of a research study, and they signed a written consent. The CTA was obtained using a MDCT scanner BrightSpeed GE 16 slices. In order to make a successful visualization of the blood vessels, the patients were appropriately prepared for the examination. They were told to be hungry 4 to 8 hours before the examination. During the procedure the patients were lying on the CT table in supine position and were advised to stay calm. The scan started at the level of thoracic inlet to include the proximal parts of the carotid and subclavian arteries and ended below the diaphragm. The slice thickness was 0.6 mm. Contrast material was injected through an 18- to 20-gauge IV catheter inserted into an arm vein, a total of 100 ml at a rate of 3 ml/s with a pressure injector, followed by a flush of 40 ml of saline administered at the same injection rate. After the contrast medium was injected, scanning was carried out automatically by using a bolus tracking software. Data were transferred to a workstation for post-processing. Reconstruction included the following: maximum intensity projection-MIP; four-dimensional CTA with volume rendering; multiplanar reformation-MPR. SYNGO software was used for post-processing (analysis). The course of the aortic arch was clearly observed in all of the 1000 patients. Each of the CT images was analyzed by 2 independent examiners.

The anatomic features of the aortic arch itself and supra-aortic vessels were analyzed, and anatomical variations were recorded on each CT image.

**Results**

The analysis of the 1000 CTA images showed that 893 of them (89.3%) had the usual pattern of the aortic arch giving rise to 3 large vessels: BCT, LCCA and LSA (Fig. 1).

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**Figure 1.** Usual pattern of the aortic arch

Variations in the branching pattern of the aortic arch were noticed in 107 (10.7%) of the patients. The examination showed that the most common variation of the number of the aortic arch branches was their reduction to two, with LCCA arising from BCT (79 of the analyzed CTA images or 7.9%) (Fig. 2).

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**Figure 2.** Left common carotid artery arising from brachiocephalic trunk

Four vessel pattern of the aortic arch was present in 28 of the patients (2.8%), with separate origin of the left vertebral artery (LVA) between the LCCA and the LSA (Fig. 3).

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**Figure 3.** Separate origin of the left vertebral artery between the left common carotid and the left subclavian artery

Examination of the aortic arch itself did not reveal right-sided, double or interrupted arch.

**Discussion**

Anatomic variations of the aortic arch and great vessels are well documented as seen during autopsies, anatomical and clinical studies. The results obtained in this study showed that 89.3% of the examined patients had the usual pattern of the aortic arch giving rise to 3 large vessels. The most common variation of the aortic arch pattern was reduction of the number of the branches to two, with LCCA arising from BCT (7.9%). Aortic arch with four branches, with separate origin of the LVA between the LCCA and the LSA was present in 2.8% of the patients. We did not find double, interrupted or right-sided arch.

At the Institute of Anatomy, a few studies of primary cardiac malformations in congenital heart diseases associated with anomalies of embryonic aortic arches and coronary circulation were done. The results of these previous examinations (Korneti, Kargovska) made on heart specimens fixed in 10% formaldehyde, showed that congenital heart diseases most often (70.9%) were accompanied with anomalies of the aortic arch (interrupted, hypoplastic, vascular ring with right aortic arch and coarctation) [18]. The analysis of the branching pattern of the aortic arch showed that the most common variation was reduction of the number of branches to two (3.6%) with LCCA arising from BCT (Zhivadinovik, 2000) [18, 19]. The second most common variation was increasing of the number of branches to four due to separated arising of LVA between LCCA and LSA (2.7%) (Kargovska, Korneti 1985) (Zhivadinovik, 2000) [18, 19].

According to literature, there are really diverse data about the percentage of the representation of the aortic arch variations [2,16 – 19]. However, the most common variation of the branching pattern occurs when the LCCA has a common origin with, or arises directly from the BCT. Another relatively common arch variation is the LVA arising directly from the aortic arch proximal to the LSA. Vucurevic *et al.* have classified the branching pattern of the aortic arch into 8 types: classical vascular pattern (type I); aortic arch with two branches or double BT (type II); aortic arch with two branches with different arising of LCCA (type III); aortic arch with four branches, with aortic origin of both carotid and both subclavian arteries, RSA arising as distal aortic branch (type IV); four vessel pattern (RCCA, LCCA, RSA, LSA) in double and right sided arch (type V); aberrant origin of LVA (type VI); aortic origin of RVA (type VII) and aortic origin of a. thyroidea ima (ThIA) [2]. In their study comprising 1265 patients the common vascular pattern was present in 74.72%. The origin of the LCCA from the BCT was the most frequent variation, which occurred in 15.56% of patients, and the LVA arising directly from the aortic arch proximal to the LSA was found in 3.63% of patients in their study [1]. According to this classification, the variations of the branching pattern in our study can be systematized as type III (7.6%) and type VI (2.8%).

According to Moore, the most frequent variation of the aortic arch is the common trunk of BCT and LCCA (11%) [17]. Hanemman *et* *al.* found out that a common origin of the BCT and LCCA, and direct origin of the LCCA from the BCT, had prevalence of 13% and 9% in the general population, respectively [14]. The same authors registered prevalence of 5%–6% for the LVA arising directly from the aortic arch proximal to the LSA. According to Gray’s anatomy, aortic arch branches may be reduced to one, more commonly two, LCCA arising from the BCT (7%), or LCCA and LSA arising from a left TCB or RCCA and RSA arising separately, in which case the latter, more often branches from the left end of the arch and passes behind the esophagus. The LVA may arise between the LCCA and the LSA or rarely (0.2%) distal to LSA. Very rarely, external and internal carotid arteries arise separately, the common carotid artery being absent on one or both sides; or both carotids and one or both vertebral arteries may be separate branches. In case of right aorta, the arrangement of its three branches is reversed. The common carotids may have a single trunk, the subclavians separate, right arising from the left end of the arch. Other arteries may branch from it, most commonly one or both bronchial arteries and ThIA [16].

An analysis of variations in branches from 1000 aortic arches made by Anson in 1963 showed the usual arch pattern in 65%, and in 27% the LCCA shared the BCT [18, 19]. An analysis made by Saadoon Kadir showed that 70% of the population had the usual pattern of the aortic arch [18, 19]. The most frequent variation was arising of the BCT and LCCA from common trunk (22%). In the same study, about 6% of analyzed cases had separate arising of LVA. According to Grant, the most common variations, which represent 73% of all variations of the number of aortic arch branches, are common trunk of BCT and LCCA (15%), and arising of the LCCA from BCT (7%) [18. 19].

Paraskevas *et al.* reported that the occurrence of the origin of LCCA from the initial portion of the BCT was 0.2% [11, 20]. According to Kumar *et al.* the frequency of LVA originating from the aortic arch was 8%.A study by Nayak *et al.* reported the classical three vessel aortic arch in 91.4% of 62 cadavers, and the LVA arising from the arch, in 1.6% of the cases [11, 21]. Bergman *et al.* reported a case of the RVA directly arising from the aortic arch, and the frequency of LCCA arising from BCT in 11% of the cases, with the LSA arising independently from the arch [11, 22].

Despite the fact that variations of the aortic arch branches are usually asymptomatic, they may cause dyspnea, dysphagia, intermittent claudication, misinterpretation of radiological examinations and complications during neck and thoracic surgery. Furthermore, these variations may be accompanied by other congenital abnormalities.

**Conclusion**

The most frequent variations of the aortic arch pattern in this study were the origin of the LCCA from the BCT and the LVA arising directly from the aortic arch proximal to the LSA. The knowledge of the anatomy of the aortic arch and its branches and the awareness of vascular variations, especially in this region, is imperative in diagnostic procedures and in planning surgical interventions during clinical practice.

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