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ORIGINAL ARTICLE

Anatomical variation of aortic arch branching patterns: An evaluation using digital subtraction angiography

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Abstract

Objective: Anatomical variations in the aortic arch branching pattern are crucial for planning surgical and endovascular procedures. These variations, often detected incidentally during radiological studies, can in- fluence the approach and success rate of interventions. This study explores to retrospectively analyze the variations in the aortic arch branching patterns using digital sub- traction angiography [DSA] and compare the findings with existing literature.

Methods: A retrospective analysis was conducted on 221 patients who underwent arcus aortography with DSA for neurovascular pathologies at the University of Ümraniye Education and Research Hospital from January 2020 to November 2022. Patients with previous thoracic-vascular surgery were excluded. The aortic arch findings were categorized according to established classifications.

Results: Six distinct aortic arch branching patterns were identified among the 221 patients. The most com- mon type was the normal or classical form [Type 1] found in 78.3% of the patients. Type 2, where the left common carotid artery originates from the brachiocephalic trunk, was observed in 19.9% of the cases. Type 3, characterized by the left vertebral artery originating directly from the aortic arch, was seen in 0.9% of the patients. Other types, including right aortic arch with aberrant right subclavian artery, were less common.

Type 3 variations were more prevalent among females, while other variations showed no significant gender difference.

Conclusion: Variations in the aortic arch branching patterns are common and generally asymptomatic but have significant implications for surgical and interventional procedures. Recognizing these variations is es- sential for improving procedural success rates and reducing complications in neurovascular interventions.

Keywords: Aortic arch; branching pattern; digital subtraction angiography; anatomical variations; neurovas- cular interventions

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Introduction

Variations of the aortic arch are categorized according to the output localization and number of vascular st- ructures that originate from the aortic arch. Most prevalent in society are the brachiocephalic trunkus, left main carotid artery, and subclavian artery, from right to left [1].

Depending on chromosomal abnormalities migration and fusion defects, can alter the number and configuration of vascular structures originating from the aortic arch [1,2,3]. Usually asymptomatic and detected incidentally during radiological studies, these variations gain significance prior to surgical and endovascular interventional procedures. In this study, we retrospectively analyzed the arcus aortographies performed with conventional angiography during diagnostic and therapeutic neurovascular interventions, comparing our re- sults with those from the literature and assessing the association between arch aortic types and neurovascular pathologies.

Methods

Patient selection

The patients who arcus aortography examinations performed with digital substraction angiography [DSA] for diagnosis or treatment of neurovascular pathologies at the interventional radiology department of the University of Ümraniye Education and Research Hospital between January 2020 and November 2022 were included in this study. Demographical-medical data and the DSA images of the patients were reviewed on the hospital database.

The patients with a previous thoracic-vascular surgery were excluded from this study.

Due to the retrospective nature of the investigation, it was not possible to get formal informed permission from the patients.

DSA technique and image analysis

5 French pig tail catheter was placed in the ascending aorta to obtain an arch aortography. The study inclu- ded a total of 221 patients. All patients' aortic arch findings were categorized from one to eight according to with the classifications established by the literature (Figure 1) [2,3].

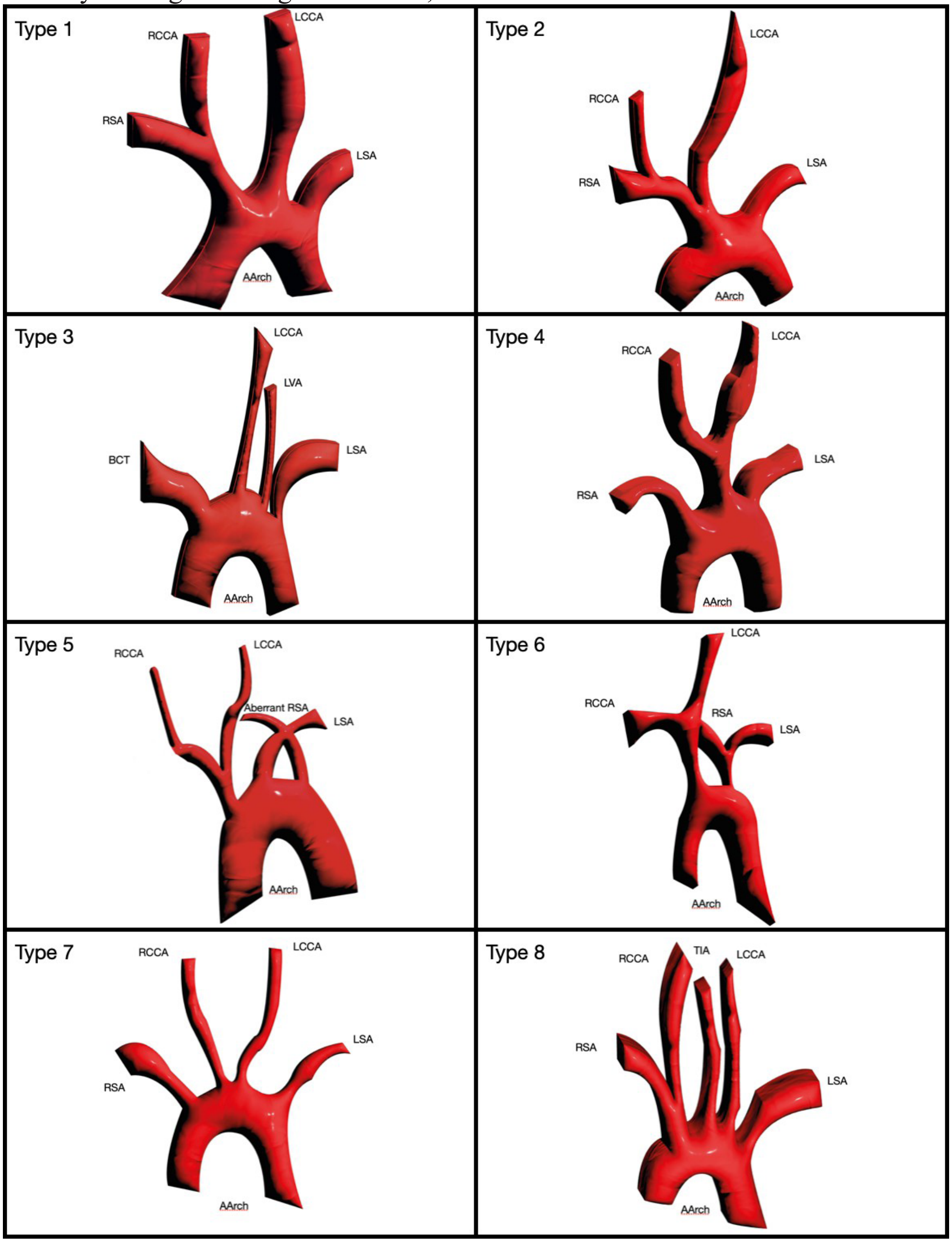

Figure 1. The image depicts the categorization of aortic arch branching patterns.

AArch: Aortic arch; LCCA: Left common carotid artery; LSA: Left subclavian artery; RSA: Right subcla- vian artery; RCCA: Right common carotid artery; TIA: Thyroide ima artery; Aberrant RSA : Aberrant sol subclavian artery.

Results

Of 221 patients, 116 were female and 105 were male, ranging in age from 19 to 99, with an average age of 57. After analyzing the 221 patients, six distinct aortic arch branching patterns were identified (Table-1). There were 173 patients who had type 1, also known as the normal or classical form. The prevalence of this arch type was 78.3%. The variation known as type 2, in which the left common carotid artery originates from the brachiocephalic trunk, was seen in 44 cases, which accounts for 19.9% of the total. In two patient [0.9%], the left vertebral artery originates directly from the aortic arch, as in Type 3 variation. Two patients presented with a right aortic arch and aberrant right subclavian artery [Figure 2]. Overall, it was noted that type 3 variations were more prevalent among females in comparison to males. Conversely, the occurrences of all other types of variations were found to be equivalent in both genders.

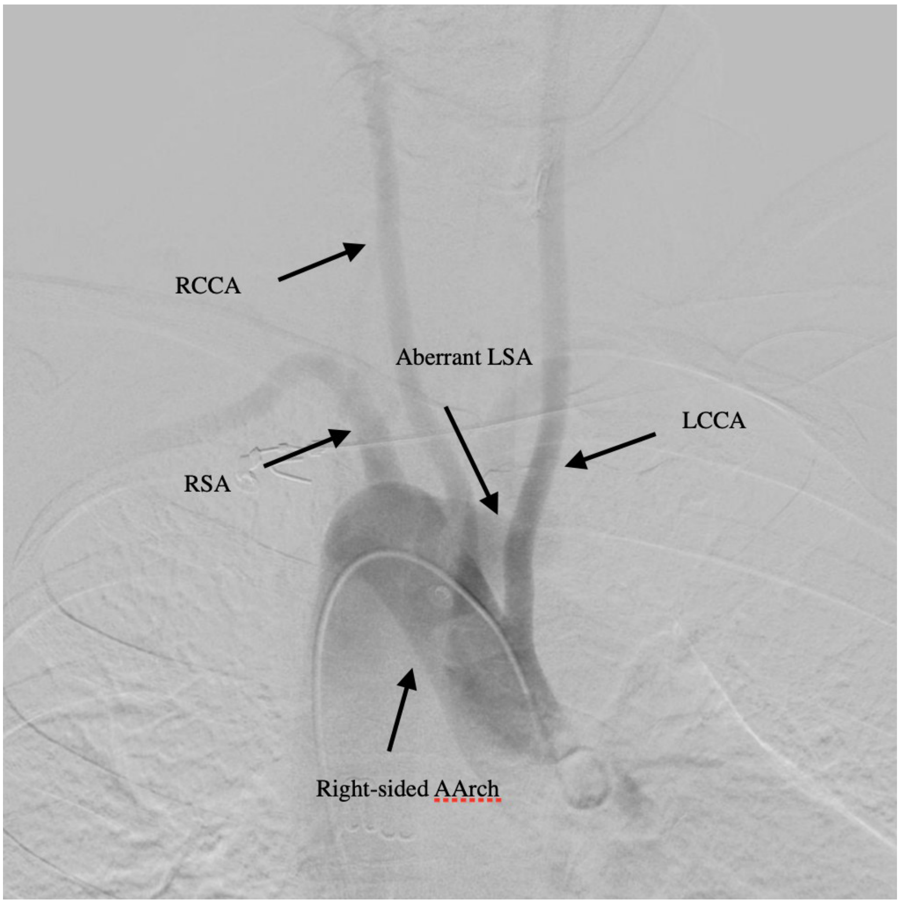

Figure 2: Right aortic arch and aberrant left subclavian artery

AArch: Aortic arch; LCCA: Left common carotid artery; LSA: Left subclavian artery; RSA: Right subcla- vian artery; RCCA: Right common carotid artery.

Table 2 presents the clinical data on variations in the aortic arch branching pattern.

Discussion

Variations in the aortic arch's branching pattern are common and usually asymptomatic. It is frequently incidentally detected. In our study, no patients exhibited symptoms such as dyspnea or dysphagia that may have been caused by the variant.

The most prevalent type of aortic arch in the population is type 1. Consequently, it is also known as the nor- mal branching pattern . Its incidence varies between 65% and 9% in previous studies [1,2,4,5]. According to the findings of our study, this is the most prevalent form, with an incidence of 78.3%.

Type II is the second most common aortic arch pattern in the literature, and its incidence ranges from 11 to 27%. The common root gives rise to the brachiocephalic trunk and the right CCA. It's also called the bovine arch [2,3,6]. In our series, bovine arch was observed in 19.9% or 44 patients. Those with type 2 aortic arch are more likely to develop thoracic aortic aneurysms, and they typically do so at younger ages [7]. In additi- on, because catheterization is more challenging during mechanical thrombectomy for acute stroke and endo- vascular cerebral aneurysm treatment in patients with bovine arch, the procedure takes longer and has a lo- wer success rate [8]. Therefore, the presence of bovine arcus detected through radiological imaging techni- ques performed for another purpose should be noted in the reports.

According to the literature, Type III aortic arch variation is the third most prevalent variation, with a preva- lence of 2.9% to 6.1% [5,9,10]. In contrast, Natsis et al. found the incidence of Type III aortic arch to be 0.79 percent in their study of 633 patients using DSA [2]. In our study, the incidence was 0.9%, which is conside- rably lower than the average in the literature. It is not clinically asymptomatic, but diagnostic imaging such as Doppler may incorrectly report it as occluded. In addition, catheterization cannot be performed during conventional angiography because it is not in its normal location, and it may be overlooked [11]. Additionally, because vertebral artery injury complications are common in spine surgery, planning should be done in terms of vertebral artery variations prior to these operations [12].

Table 1. The rate and gender distribution of aortic arch branching pattern variations.

Variation	Description	All (n=221)	Male (n=105)	Female (n=116)
Type 1	Normal aortic arch branching	173 (78.3%)	86 (81.9%)	87 (75%)
Type 2	Bovine aortic arch	44 (19.9%)	17 (16.2%)	27 (23.3%)
Type 3	LVA originating from the aortic arch	2 (0.9%)	1 (1%)	1 (0.9%)
Type 4	Existence of both types 2 and 3	-	-	-
Type 5	Aberrant right subclavian artery	-	-	-
Type 6	Bicarotid trunk coexistence	-	-	-
Type 7	Right and left subclavian and common carotid arteri- es originate separately.	-	-	-
Type 8	TIA that arises in the aortic arch	-	-	-
	Right aortic arch and aberrant left subclavian artery	2 (0.9%)	1 (1%)	1 (0.9%)

LVA = left vertebral artery ;TIA= thyroida ima artery

In the literature, a Type IV aortic arch variation is described where the brachiocephalic trunk is absent, and the right and left subclavian arteries arise directly from the aortic arch, with the common carotid arteries emerging from a single bicarotid trunk [9,13]. In the literature, 0.7% incidence of type IV aortic arch has been reported [13]. In our study, type IV aortic arch was not observed. Clinically, the bicarotid trunk is the leading congenital cardiovascular anomaly most frequently responsible for tracheobronchial compression [14,15].

In Type V aortic arch, both common carotid arteries arise from a single trunk, while the left subclavian artery and an aberrant right subclavian artery originate separately [2,5]. This anatomical variation, with an inciden- ce of about 0.7% [6]. The aberrant right subclavian artery is the last branch to emerge from the aortic arch and typically crosses from the left side of the body to the right, often passing behind the esophagus, a condi- tion known as arteria subclavia dextra lusoria(ASDL).The incidence of an aberrant right subclavian artery alone is found in 1.4% of people, with reported rates ranging from 0.13% to 25% [10,11]. It can lead to clini- cal issues such as dysphagia lusoria, where esophageal compression causes difficulty swallowing [14,15]. In some cases, the ASDL may also course between the trachea and esophagus or in front of the trachea, potenti- ally causing dyspnea or complications during tracheostomy. Additionally, this variation can present challen- ges during right arm catheterization in angiographic procedures [2,15,16].

Type VI aortic arch variation is comparable to type V, with the exception that both common carotid arteries arise from a single branch. The aortic arch gives rise to two major branches. It is rarely observed [16,17]. Its clinical significance is dependent on the aberrant course of the right subclavian artery, as in type V arch.

In aortic arch type VII, the right subclavian artery, the right common carotid artery, the left common carotid artery, and the left subclavian artery arise independently. It is extremely uncommon and has no clinical mani- festations.

In addition to type I aorta, the thyroid ima artery originates from the aortic arch in type VIII aortic arch. Its incidence was reported to be 0.16 percent [2]. It is clinically silent, but there is a risk of injury during neck- region surgical procedures. It is also susceptible to injury during angiography.

The incidence of right aortic arch anomaly in the

Table 2. The clinical data of variations in the aortic arch branching pattern.

Clinical data	Type 1 (n=173)	Type 2 (n=44)	Type 3 (n=2)	R-A Arch, aRSA (n=2)	Total
AVM	10 (71.4%)	4 (28.6%)	0	0	**14**
Aneurysm	76 (77.6%)	19 (19.4%)	2 (2%)	1 (1%)	**98**
CAS	37 (90.2%)	4 (9.8%)	0	0	**41**
Stroke	18 (69.2%)	7 (26.7%)	0	1 (3.8%)	**26**
Behçet	1 (100%)	0	0	0	**1**
SAH	29	10 (25.6%)	0	0	**39**
Moya Moya	1 (100%)	0	0	0	**1**
AVF	1 (100%)	0	0	0	**1**
Total	**173 (78.3%)**	**44 (19.9%)**	**2 (0.9%)**	**2 (0.9%)**	**221**

R-A Arch, aRSA =Right aortic arch, aberrant right subclavian artery;AVM=Arteriovenous malformation; CAS=Carotid artery stenosis; SAH=Subarachnoid hemorrhage; AVF=Arteriovenous fistula

population has been estimated between 0.05% and 0.2% [18]. A right aortic arch and a mirror-like arch branching were observed in two cases [%0.9] in our study. According to Terziolu et al.'s study, its prevalence was 0.2%. In two of our patients, the right aortic arch and aberrant left subclavian artery anomaly were described. Left common carotid artery, right common carotid artery, right subclavian artery, and left subclavian artery originate from the aortic aorta, respectively. As the aberrant left subclavian artery moves from right to left in the mediastan, it may pass behind the esophagus and result in compression symptoms. In addition, the left subclavian artery may exhibit an enlargement at the aortic outlet, known as a commerel diverticulum. Its prevalence has been estimated at 0.1% to 0.3% [9,19].

In addition, it has been demonstrated that the risk of cerebrovascular disease increases in certain aortic arch branching variations. Depending on the artery's angle and exit level, the flow hemody- namics in the principal arterial structures originating from the aortic arch vary [Table 2]. According- ly, the death rate from cerebrovascular disease is higher in type 2 and type 3 aortic arch variations than in type 1 aortic arch variations [20].

This study has several limitations. First, the patient population was limited to those treated at a sin- gle hospital, which may affect the generalizability of the findings. Second, the retrospective nature of the study could introduce bias, and the absence of a control group limits the strength of the con- clusions. Finally, genetic and environmental factors were not considered, which could influence the presence of aortic arch variations.

The prevalence of endovascular treatment for cerebrovascular diseases has increased in recent years. Catheterization of supraaortic arterial structures requires the aortic arch. Particularly in type 2 and type 3 aortic variants, the catheterization time of supraaortic arterial structures and the corresponding radiation dose exposure increase proportionally. In addition, the catheterization time is crucially important for stroke patients undergoing mechanical thrombectomy.

Conclusion

In conclusion, variations in the aortic arch are common in imaging studies. It is essential to recognize these variations because they both set the stage for cerebrovascular diseases and cause symptoms by compressing structures such as the esophagus and trachea. Additionally, it is essential to have a thorough understanding of the aortic arch's anatomy prior to certain surgical interventions and endovascular diagnostic and therapeutic procedures in order to achieve a low complication rate and high procedural success.

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