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Standardized Classification for Aortic Arch Branching Patterns (SCAABP)

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Abstract

Objectives: To review current anatomical classifications for the aortic branching patterns and propose a method for Standardized Classification for Aortic Arch Branching Patterns (SCAABP).

Methods: Through a three-stage Delphi method, expert vascular anatomists in morphology design SCAABP to report trunks, branches, and laterality of aortic arch branching patterns.

Results: SCAABP is a classification that includes 7 parameters (Number of branches, and 6 types of branches [brachiocephalic trunk, common trunk, common carotid, subclavian artery, vertebral artery, and ectopic arteries]). It can integrate all reported branching patterns and allows the classification of new or unreported patterns. The classification allows standardization for future comparison of results, and improvement of evidence-based anatomy.

Conclusions: SCAABP is a standardized method for classifying anatomical variants of the aortic arch. It is simple, clear, and contemplates new variants. All reported classifications can be integrated.

Key Words: *Aortic arch; Branching pattern; Anatomical variants; Standardized classification; SCAABP*

Introduction

The aortic arch is one of the main arterial trunks in the human body. The brachiocephalic trunk, the left common carotid artery, and the left subclavian artery originate from the aortic arch up to 85% of the time [1].

Reports of anatomical variants have been published throughout the 20th century, however, classification methods have varied. The prevalence of branching patterns ranges between 5% and 35%, depending on populations [2-4]. These are of clinical importance during surgical and interventional procedures, to avoid complications and negligence [5]. Some studies have hypothesized or correlated branching patterns with risk of other diseases or complications (hypertension, aneurism, dissection, intramural hematoma, rupture, bicuspid aortic valve, etc.) due to the anatomical changes, as well as the vascular physiologic mechanisms implicated [4,6].

Patients with cardioembolic stroke are reported in the literature as the most prevalent, having great importance in patients with auricular fibrillation. The aortic arch branching pattern is related to the laterality in which the cerebrovascular accident occurs, being the left anterior hemisphere the most affected. For instance, patients with a bovine arch variant have a higher predilection of emboli traveling to the left cerebral hemisphere. Additionally, the frequency in which the stroke occurs in relation to the dominant hemisphere (being the left hemisphere dominant in 90% of the population) can be associated with a worse outcome for the patient. However, the patient will present more notable and recognizable symptoms, resulting in faster transportation and medical assistance. This significance of the branches´ morphometry creates a necessity for

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standardized definitions in modern studies [7,8].

A recent (2018) systematic review of reported variants in the branching patterns determined the bovine arch (13.6%) and the added left vertebral artery (2.8%) variants as the most prevalent. They also concluded a higher variability in Africa and South America regions [4,9,10].

With several reports of anatomical variations, Natsis et al., (2009), classified the aortic arch branching pattern according to the order of prevalence in their results. These were numbered from I to VIII, being type I the most frequent and type VIII the least [11]. Although an increasingly popular classification, it does not contemplate other variants, forcing authors to modify it, causing duplicability of types with different branching patterns, or misinterpretation of a new type, due to small variabilities. Other recent studies report their results using different classifications causing confusion among types, making data interpretation difficult between studies leading to excess classifications based on the findings of each author [12-16]. A standardized classification method is lacking, and there is no justification to use one over another, other than their popularity or cite impact.

Similarly, hernia pathology had over a dozen different classifications. Each with its own characteristics, according to the region, which did not allow for viable comparison of results during reviews and metanalyses. A group of experts decided to change these popular, yet historic classifications, for a standardized method of reporting data [17,18]. This has led to a clear classification for all authors to follow.

Evidence-based medicine has led the way through the 21st century. Anatomy has adapted as well, with evidence-based anatomy and quality recommendations for reporting anatomical studies [19-23]. These have allowed the publication of reviews and metanalyses regarding anatomical variability and its clinical relevance. The aim of this study was to review current anatomical classifications for the aortic branching patterns and propose a method that would allow a Standardized Classification for Aortic Arch Branching Patterns (SCAABP).

Materials and Methods

Delphi method for SCAABP was performed. A review of the multiple classification systems that evaluates the branching patterns of the aortic arch has been studied. The results of these publications were included and ordered depending on the characteristics described in each section. Any study that reported anatomic variants in the aortic arch branching was considered, including those studies with atypical results that have not been compatible with findings in other studies.

A committee was formed with published experts in vascular morphology, to perform the Delphi protocol with the purpose of redefining and editing existing classifications. The new classification design must contemplate unreported variants, to avoid the adding of new types, as has been the case with the existing classifications.

A preliminary classification was designed to report trunks, branches, and laterality of aortic arch branching patterns. The committee reviewed the proposed classification providing feedback. A new version based on the revisions was created and revised again by the committee members. The classification was improved by further comments, and then tested for applicability with existing classifications, and internally validated (Figure 1). The most prevalent types of branches originating from the aortic arch are the brachiocephalic trunk (BT), common carotid (C), subclavian (S), vertebral artery (V), a common trunk (CT), and less frequently other ectopic arteries (E).

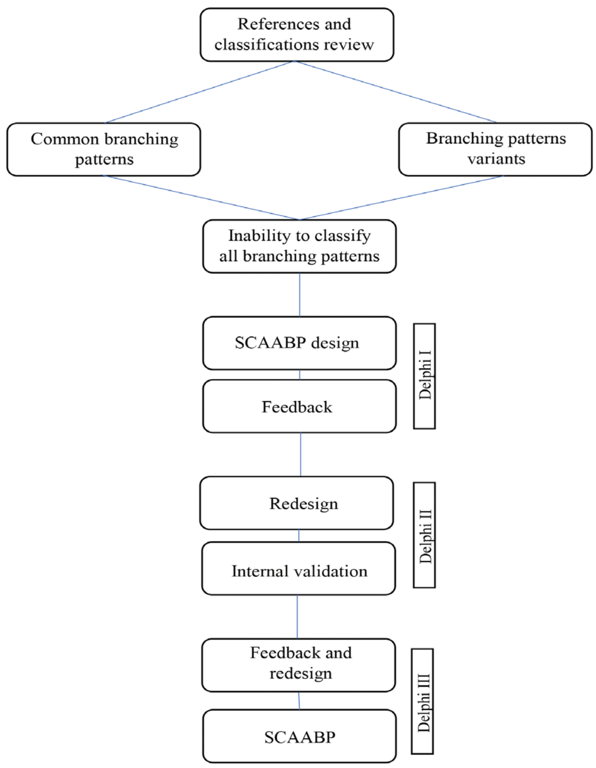

Figure 1) *Development of the SCAABP Classification.*

Results

A standardized classification for the aortic arch branching pattern was developed (Table 1). To avoid the use of proper or common names, as well as the memorization of types, each type must include the initials of the prevalent branches with a subscript to specify quantity and laterality. The existing classifications and variability in types are classified using this method in Table 2.

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TABLE 1
Standardized Classification of aortic arch branching pattern (SCAABP).

Number of Arteries	Brachiocephalic trunk	Common Trunk	Common Carotid	Subclavian	Vertebral	Ectopic
#	BT_{0RL}	CT_{0RL}	C_{0RL}	S_{0RL}	V_{0RL}	E_{0RL}

BT=Brachiocephalic Trunk; **CT**=Common Trunk; **C**=Common Carotid; **S**=Subclavian; **V**=Vertebral; **E**=Ectopic; **0**=none; **R**=Right; **L**=Left.

TABLE 2
Variability in the classifications of the aortic arch branching patterns.

Other types classified	3, BT_R, CT_0, C_0, S_L, V_L, E_0	4, BT_R, CT_0, C_L, S_L, V_0, $E_L^{THYROID}$	4, BT_0, CT_0, C_{RL}, S_{RL}, V_0, E_0	2, BT_0, CT_{RL}, C_0, S_0, V_0, E_0	3, BT_0, CT_R, C_0, S_{LAR}, V_0, E_0	3, BT_0, CT_R, C_0, S_{RL}, V_0, E_0	4, BT_R, CT_0, C_L, S_L, V_L, E_0	2, BT_0, CT_R, C_0, S_L, V_0, E_0	3, BT_R, CT_0, C_L, S_L, V_0, E_0	SCAABP
6 other types (B, G, I, J, IJ, K)		Pattern F		Pattern H	Pattern E		Pattern D	Pattern C	Pattern A	**De Garis et al 1933**
10 other types (BE, BK, CG, E, EL, G, K, L, M, N)	Type D	Type F		Type J	Type H		Type C	Type B	Type A	**McDonald et al 1940**
9 other types (V, VI, VII, VIII, X, XI, XII, XIV, XV)	Type IV	Type XII		Type IX			Type III	Type II	Type I	**Liechty et al 1957**
2 other types (C, F)				Type G		Type E	Type D	Type B	Type A	**Makhanya et al 2004**
		Type 8	Type 7	Type 6	Type 5	Type 4	Type 3	Type 2	Type 1	**Natsis et al 2009**
1 other type (IIB)							Type III	Type IIA	Type I	**Patil et al 2012**
1 other type (G)	Type E		Type C		Type F		Type D	Type B	Type A	**Acar et al 2013**
				Type VI	Type V	Type IV	Type III	Type II	Type I	**Ergun et al 2013**
1 other type (V)				Type IV			Type I	Type III	Normal	**Rekha et al 2013**
4 other types (II, IV, V, VII)		Type VIII					Type VI	Type III	Type I	**Vučurević et al 2013**
							Type C	Type B	Type A	**Durai Pandian et al 2014**
			Type VII	Type VI	Type V	Type IV	Type III	Type II	Type I	**Karacan et al 2014**
1 other type (Aberrant Right Subclavian)							Isolated	Bovine	Normal	**Dumfarth et al 2015**
3 other types (IX, X, XI)		Type VIII	Type VII	Type VI	Type V	Type IV	Type III	Type II	Type I	**Huapaya et al 2015**
				Type C	Type D		Type B		Type A	**Kondori et al 2016**
5 other types (4c, 4d, 5a, 5b, 6a)	Type 4b			Type 3	Type 6b		Type 4a	Type 2	Type 1	**Mustafa et al 2016**

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User's Guide to SCAABP

The classification includes 7 parameters (Number of branches, and 6 types of branches [BT- CT- C- S- V- E-]), which must be all included when describing any aortic arch (Table 1). After defining the limits of the aortic arch, the number of branches must be identified, to establish the first parameter. There is no limit to the number of branches, although it will most likely vary between 1 and 4. The number placed in this parameter must equal to the number of "R" and "L" placed in the following 6 types of branches.

The 6 types of branches (BT- CT- C- S- V- E-) must always be included, followed by a subscript. The subscript option can be "0" if this branch is not present or specified as "R" or "L" depending on the laterality of the branch. The quantity of this branch is determined by the number of "R" or "L" placed as a subscript. These can be repeated if there are more than one of these branches on the same side (i.e. two right common carotids, and one left common carotid=CRRL) or preceded by an "A" in case of an aberrant branch (i.e. aberrant right subclavian and a normal left subclavian=SARL). In the case of an uncommon artery originating from the arch, this can be classified as right or left ectopic "E" and branch written in superscript (i.e. left bronchial artery= ELBronchial). In the case of a situs inversus, the word "inversus" should be used before the SCAABP to specify.

Discussion

SCAABP provides a clear classification method, without the need of memorizing types, and avoiding the confusion of the differences between classifications. It is also a flexible classification that contemplates un-described or un-published variants, to avoid modifications to the existing classifications, or the existence of same types with different branching patterns, due to publications by different authors proposing modifications to the current classifications. Table 2 shows how different types of branching patterns from various classifications, can easily be integrated into SCAABP.

A study analyzed the aortic arch based on the vertical distance from the origin of the brachiocephalic trunk to the highest point of the arch in a parasagittal view, if the diameter is less than 1 it is classified as type I, if it is between 1 and 2 it is considered type II, and if it is greater than 2 it is named type III. They found type I was more prevalent while type III showed the inconvenient of being more related to complicated arterial accesses at the aortic level [24,25].

The angulation and the relationship between altitude and latitude determine the aortic arch in three types: Romanesque, crenel, and gothic aortic arch. The importance of these morphological characteristics lies in procedures such as arterial repair due to coarctation of the aorta, being the gothic aortic arch an independent risk factor for anatomical and functional deleterious changes of the arteries prior to the coarctation. The Romanesque aortic arch maintained localized anatomical changes in arteries after the aortic coarctation [26].

It has been shown the relationship between the Gothic arch and exercise-induced hypertension in patients who underwent to coarctation repair of the aorta. No risk of exercise-induced or resting hypertension was demonstrated with the Crenel aortic arch [27].

A standardized classification is a world tendency for many pathologies [17,18]. This will grant unification of data, reproducibility, and facilitate comparison of results between studies allowing improved evidence-based anatomy in future revisions to correlate these clinically. Branching patterns show a promising marker for identifying the risk to other vascular or physiological diseases, although more studies are needed [6]. It may also aid in determining if geographical factors play a role due to differences in prevalence per region, as concluded by Popieluszko et al. [4].

Limitations. SCAABP has not been validated externally. A prospective study is needed to include 3D reconstructions of imaging studies or illustrations for anatomists to determine if the patterns are classified accordingly. Common trunks are not further explained by the classification, as these are no longer branches of the aortic arch. The user can presume the probable branches by those missing from the aortic arch, but this is not included in the classification to avoid complexity.

Conclusion

SCAABP is a standardized method for classifying anatomical variants of the aortic arch. It is simple, clear, and contemplates new variants. All reported classifications can be integrated. It allows for improved data publication to promote evidence-based anatomy.

Author Contribution Statement

Mariana Tapia-Nañez and Alejandro Quiroga-Garza participated equally and are both accredited with the role of first authors. All authors participated in the design and validation of the classification, as well as the writing and editing of the final manuscript version. Rodrigo E. Elizondo-Omaña is head of the project and supervised all stages.

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