Type of Manuscript:
Full Article

e-ISSN: 2595-5527
Doi: 10.32435/envsmoke-2024-0005
Volume 7, 2024
Manuscript ID: es20240005
(01-06)

ENVIRONMENTAL SMOKE

ANATOMICAL VARIATIONS OF THE VERTEBRAL ARTERY AND THEIR IMPLICATIONS

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Abstract

The Vertebral arteries correspond to a pair of vessels that originate from the superior branch of the 1st portion of the A. Subclavia. In general, they present general anatomical variations regarding the length and diameter of the lumen, with the left being larger than the right. More extreme variations, such as the absence of one of the arteries, due to agenesis or involution, are generally related to craniovertebral defects. The objective of this work was to evaluate the anatomical variations found in the vertebral arteries and to discuss their clinical implications. In the construction of this study, a descriptive research, of the RIL type, was carried out, fulfilling all the stages of development. The search resulted in 23 articles. After reading, the corpus was composed of 12 articles, whose potential content was dedicated to investigating the type of anatomical variation of the vertebral artery and its implications and harms in the health of the carriers. Symmetrical vertebral arteries are found in about 26% of individuals. Marked differences in the diameter of the arteries, called Vertebral Artery Dominance (VAD) result in a significant decrease in the blood flow velocity of the artery and an increase in the resistance index (RI). The incidence of infarction in the posterior region of the brain is significantly higher in individuals with VAD. Infarctions occurred more frequently on the side of the non-dominant vertebral artery, probably due to non-mixing of Aa blood. vertebral arteries within the A. basilar, which run separately and with a central zone where flow is absent, called the "dead spot". Changes in normal blood flow were tested to determine their correlations with sites of thrombosis and atherosclerosis in humans. The agenesis of some branches of A. vertebral is also identified as an important factor for the occurrence of strokes in the posterior region of the brain.

Keywords: Vertebral Arteries. Stroke. Resistance Index.

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Submitted on: 26 Aug. 2023
Accepted on: 29 Mar. 2024
Published on: 11 Apr. 2024

1 Introduction

The Vertebral arteries correspond to a pair of vessels that originate from the superior branch of the 1st portion of the A. Subclavia, medially to the M. anterior scalene. In their ascending path inside the transverse foramina of the first 6 cervical vertebrae, they cross the foramen magnum, perforate the dura mater and arachnoid meninges and after a short path inside the skull, they unite to form the Basilar artery. Together, the Aa. vertebral and basilar (Aa. vertebrobasilar) and their branches form the posterior circulation of the brain (GRAY; GOSS, 1988; MOORE, 1994; SMITH; BELLON, 1995; ZHU et al., 2016).

The right and left vertebral Aa present general anatomical variations regarding the length and diameter of the lumen, with the left being larger than the right. Individual anatomical variations, such as the position of their origin, are relatively uncommon and estimated to be around 5% of individuals. When present, the vertebral artery arises, in most cases, directly from the aortic arch or from the A. thyrocervical trunk. More extreme anatomical variations such as the absence of one of the arteries, due to agenesis or involution, are rare and are usually related to craniovertebral defects (MOORE, 1994; GRAY; GOSS, 1988; SEIDEL et al., 1999; WANG et al., 2009; TETIKER et al., 2014; BLACKBURN et al., 2017).

In some cases, one of the vertebral arteries has a diameter below normal and its flow is compensated by the contralateral vertebral artery, which has an increased diameter and blood flow. These hypoplastic vessels may not merge with the other vertebral artery, and in these cases, the basilar artery is formed by the continuation of the hyperplastic vertebral artery.

In rarer cases, A. vertebral can present distal stumps in a blind end. These rudimentary structures, resulting from incomplete embryonic involution, can be confused with aneurysms and lead the individual to unnecessary surgical treatments (KOMIYAMA et al., 2001).

In this context, it is evident that knowledge of cerebral vascularization and its variations is important for a good diagnosis and treatment of brain problems (BLACKBURN et al., 2017).

The objective of this work was to evaluate the anatomical variations found in the vertebral arteries and to discuss their clinical implications.

2 Methodology

In the construction of this study, a descriptive research, of the RIL type, was carried out, fulfilling the development stages: identification of the theme and selection of the research question; establishment of eligibility criteria; identification of studies in databases; evaluation of selected studies and critical analysis; categorization of studies; evaluation and interpretation of results; and data presentation in the RIL structure (WHO, 2020).

Considering the methodological rigor for review studies in line with Evidence-Based Practice (EBP), which provides for the identification of evidence contained in investigations carried out, the PICO strategy was used (BERNARDO et al., 2004, WHITTEMORE, 2005), which represents an acronym - Patient or Problem, Intervention, Comparison and Outcomes (outcome), which makes it possible to elaborate the research question and search strategies.

The RIL began with the elaboration of the guiding question P (vertebral arteries), I (group analysis), C (anatomical variations) and O (increase in health problems): what is the scientific evidence regarding the relationships between anatomical variation found in the vertebral arteries and the increased incidence of injuries in the posterior brain region, made available online, in newspapers with national and international circulation, published in the last 10 years?

To compose the research corpus, articles were searched on the internet between the months of June and July 2021. The primary search was carried out in the following databases: Web of Science, CINAHL and PubMed. To ensure a wide and thorough search, the keywords and descriptors were delimited in the Thesaurus according to the Medical Subject Headings (MeSH) database, as well as the guiding question raised. The Boolean operators AND and OR were used. For search refinement, the qualifier classification (/CL) was used for the descriptor “Anatomy” and the symbol * to truncate the descriptor “Anatomy” and the keywords “variation” *; “vertebral artery”, as shown in (chart 1). In order to avoid biases in the search and selection of articles, it was carried out by two researchers in a blind and independent manner.

To select the sample, the following inclusion criteria were used: primary source articles indexed in the databases, published between June and July 2021, in Portuguese, English or Spanish and available in full. Exclusion criteria were: review articles and not presenting the keywords in the title or abstract of the selected articles, duplicate studies were considered only once.

The search process followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (BERGMAN, 2011).

3 Results and Discussion

The search resulted in 23 articles, of which 1 was excluded for duplicity and 7 for not having the descriptors in the title or abstract. After the complete reading of 16 articles, 4 were excluded because they did not fit the objectives proposed in the RIL. In this way, the corpus was composed of 12 articles, whose potential content was dedicated to investigating the type of anatomical variation of the vertebral artery and its implications and harms in the health of the carriers.

Anatomical variations correspond to alterations in the topography and/or morphology of body structures that present a normal pattern within the population. These variations appear in different ways, and may have their origin in the persistence of embryonic structures, in premature or late formation during angiogenesis, in the absence of or inadequate formation of the structure (SIKKA; JAIN; 2012). By definition, anatomical variations do not promote losses in the functions of the organ in question, and in some cases, it may even benefit the bearer (SIKKA; JAIN; 2012). However, variations of Aa. Vertebral nerves have shown to be of significant diagnostic importance, especially in pre-surgical examinations of the neck region or intravascular diseases, such as arteriovenous malformations, cerebral aneurysms, thrombosis, among others. These injuries may be the result of alterations in hemodynamics suffered by the variation in the normal pattern of the vessel (PATASI, et al., 2013).

The anatomical variations found in the vertebral arteries (VA), although of a low percentage, have been pointed out by some authors as natural agents for the occurrence of important alterations in the blood flow of the posterior region of the brain, which has led to serious disturbances and even the death of individuals with such variations. Symmetrical right and left vertebral arteries are found in about 26% of individuals. The left VA often has a larger diameter. Some anatomists suggest that this pattern is due to the origin of the left subclavian artery, which arises directly from the arch of the A. aorta and thus is subject to greater pressure (MOORE; 1994; GRAY; GOSS; 1988; JENG; YIP; 2004; PERREN et al., 2007; AKGUN et al., 2013; ZHU et al., 2016).

The accentuated difference in the diameter of the vertebral arteries can be called Vertebral Artery Dominance (VAD), although this denomination is not accepted by all authors. Thus, it is also common to find the term Vertebral Artery Hypoplasia (VAH).

VAD or HAV occurs when one of the arteries has a diameter of at least 30% greater than the contralateral artery (SMITH; BELLON; 1995; ZHU et al., 2016) and the flow of the vertebral artery is referred to as pathological when lower at 100 ml per minute (SEIDEL et al., 2099; JENG; YIP; 2004).

Some studies describe VAD as a significant decrease in artery blood flow velocity and increase in resistance index (RI) for vertebral artery diameters less than or equal to 2.5 mm (JENG; YIP; 2004; PERREN et al., 2007).

VAD can lead to deformations in the morphology of the vertebrobasilar system, such as curvatures and/or changes in the length of the basilar artery, resulting in an increase in the incidence of infarcts in the posterior region of the brain (ZHNG et al., 2014; ZHU et al., 2016) . There are also reports of infarcts due to obstruction or insufficiency of the posterior inferior cerebellar artery and lateral medullary artery in individuals with ipsilateral VAD (HONG et al., 2009; ZHU et al., 2016).

The incidence of infarction in the posterior region of the brain is significantly higher in individuals with VAD than in individuals without A. vertebral dominance (control group), regardless of the prevalence of other related factors such as age, gender, hypertension, diabetes mellitus, smoking, alcoholism, hyperhomocysteinemia and lipid metabolic disorders. The incidence of infarcts in the circulation territory of the posterior region is 3 times higher than in other territories (ZHU et al., 2016; PERREN et al., 2004).

The infarcts occurred more frequently on the side of the non-dominant vertebral artery, that is, on the hypoplastic side. This picture was observed both for the regions supplied by the Aa. posterior inferior cerebellar and for the region supplied by the proximal portion of the A. basilar. The regions supplied by Aa. superior cerebellar and Aa. posterior brain, showed no significant difference between the groups with and without VAD (ZHU et al., 2016). Similar results were found by Neri et. al., (2021) in patients with benign paroxysmal positional vertigo, the most frequent cause of vertigo.

These last results can be explained by the non-mixing of Aa blood. vertebral arteries inside the A. basilar, which follow separately and with a central zone where the flow is absent, called the "dead spot” (SMITH; BELLON; 1995; CHONG et al., 1994; NERI et al., 2021). Studies have shown a pattern of blood flow in the basilar artery corresponding to the contributions of each vertebral artery individually, findings by Smith and Bellon (1995) who showed this pattern of non-mixing of blood flow in the basilar artery in 94% of the patients evaluated.

Two blood flow patterns were identified within the A. basilar without blood mixing, one parallel and one spiral. In the parallel pattern, the blood remained ipsilateral throughout the entire length of the A. basilar or most of it. This pattern was found in about 80% of subjects. The spiral pattern was found in the rest of the cases and evidenced the blood in revolving flow inside the A. basilar (SMITH; BELLON; 1995).

In a group of volunteers who presented dominance in one of the vertebral arteries, it was evidenced that in 100% of the volunteers the Aa. posterior cerebral arteries received the highest blood supply from the dominant A. vertebral. However, in nearly 40% of cases, hypoplastic vertebral A. only contributed to ipsilateral posterior cerebral A., and in nearly 40% of cases, it contributed only to ipsilateral anterior cerebral A. In the absence of dominance, the blood supply to the posterior cerebral A. came from the a. ipsilateral vertebral column (SMITH; BELLON; 1995).

In that study, approximately 80% of the patients who suffered an infarction in the posterior inferior cerebellar artery circulation occurred on the side opposite the VAD. In the cases of infarction in the A. basilar circulation, 75% were on the same side as the A. vertebral dominance (ZHU et al., 2016).

Blackburn et. al. (2017) report the dissection of a 79-year-old man who had suffered a stroke, showing a hypoplastic right vertebral artery (about 2mm in diameter) and an enlarged left vertebral artery (more than 6 mm in diameter). Due to compensatory blood flow. In this finding, it was observed that the basilar artery was formed only by the hyperplastic left vertebral artery. The right and left posterior inferior cerebellar arteries also arise from the left vertebral artery. The right vertebral artery terminated as a posterior spinal artery.

In the case above, an obstruction of the left vertebral artery would cease all circulation in the posterior region of the brain, causing the stroke and leading to the individual's death due to the absence of the contralateral flow. In addition, the greater diameter of the A. vertebral, due to enlargement, could lead to compression of the bulb, cranial nerves in the posterior region of the brain, cranial fossa and even the cerebellum (BLACKBURN, et al., 2017).

Decreased blood flow due to differences in Aa caliber. Vertigo has also been implicated as a cause of the occurrence of benign paroxysmal positional vertigo, a relatively common disorder characterized by the sensation of spinning in response to false changes in head position. (NERI et al., 2021). This is due to the fact that capillary flow in the posterior circulation of the brain is directly proportional to reductions in flow in the vertebral arteries. (SUTALO et al., 2014).

This flow relationship was also perceived by Sutalo et al., (2014) when verifying that vasoconstriction in the peripheral vasculature of the posterior cerebral A. resulted in a marked decrease in the flow of the Aa. vertebral arteries and that vasoconstriction in the peripheral vasculature of the Aa. posterior cerebral and middle cerebral arteries decreased the flow of the Aa, internal carotid arteries. These findings were pointed out as alternatives for the formulation of non-invasive techniques in the diagnosis of vasoconstriction in different sections of the brain, justifying that the monitoring of changes in flow in these large arteries could indicate the presence of diseases or injuries in regions supplied by the small cerebral vasculature.

Another important aspect that must be observed in the anatomical variations of the Aa. vertebrae relate to the path. Kim et al., (2009) described two findings by means of angiography and MRI of variations in the course of these vessels. The first in a 71-year-old patient who complained of severe headache and was diagnosed as having an aneurysm in the right paraclinoid portion. This patient had the left A. vertebral originating directly from the aortic arch and the right A. vertebral originating from the right common carotid artery. Both Aa. The vertebrae ascended in front of the C6 and C5 vertebrae and only penetrated the transverse foramen of C4. The second case involved a 52-year-old patient with dizziness, diagnosed with a hypervascular mass in the right cerebellopontine angle caused by a congenital arteriovenous malformation in this region. The patient also exhibited a right vertebral A. arising from the right A. common carotid artery.

Similar findings from Aa. vertebral bodies originating directly from the arctic arch was described by Sikka & Jain (2012), who observed the left A. vertebral starting from this position and entering the transverse foramen of the ipsilateral 4th cervical vertebra. The right vertebral artery, although it started from the A. subclavia, appeared very close to the right common carotid artery and only entered the transverse foramen from the 3rd cervical vertebra.

Vertebral arteries that present a tortuous appearance are also at greater risk for iatrogenic injuries at any age during manual therapy, surgical procedures or physical trauma (MORRIS et al., 2011; BLACKBURN, et al., 2017).

Changes in normal blood flow caused by a given vessel geometry, such as vessel lumen size, stenosed or tortuous areas, were tested to determine their correlations with sites of thrombosis and atherosclerosis in humans. In these experiments, atherogenesis was more evident in places with lower flow velocity and also in points of greater shear stress fluctuations, one of the precursors of the formation of atheromatous plaques. (SMITH; BELLON;1995).

The agenesis of some branches of the A. vertebral artery is also identified as an important factor for the occurrence of strokes in the posterior region of the brain. Akgun et al., (2013) showed that a total of 63% of patients suffering from stroke in the posterior region of the brain had at least one anatomical variation in the vertebrobasilar circulation. Of a total of 135 patients, the most common variation was isolated agenesis of one of the posterior inferior cerebellar arteries, with 24.4% of the cases on the right side and 19.3% on the left side. In these cases, it was verified that the blood supply came from the well-developed ipsilateral anterior inferior cerebellar A. or by an anastomosis of the contralateral anterior inferior cerebellar A. (AKGUN et al., 2013).

4 Conclusions

Variations of the vertebral arteries are clinically important anatomical findings because they are directly involved in the occurrence of low to high complexity diseases. Its presence leads to changes in blood flow that can result in headaches, vertigo, heart attacks and a multitude of iatrogenic diseases.

In this context, knowledge of the anatomical characteristics of the vertebral AA and their branches plays an important role in the diagnosis, treatment and preoperative planning of brain circulation problems.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

MAJC and SEJC conceived the idea for this review. FESS and CMAFM designed the review protocol, and AOO, MAJC, and SEJC conducted the search, all authors read and screened citations, abstracts, and full texts. MAJC, performed the data extraction, as well as the consultation with CMAFM, conducted the data analysis. SEJC, FESS and GDF contributed substantially to the final construction of the review, MAJC and GDF prepared the manuscript. All authors reviewed and provided their feedback and approved the manuscript in its final version.

DECLARATION OF INTEREST

The authors have no conflicts of interest.

FUNDING SOURCE

No financial assistance was obtained for this study.

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