

CORRELATION BETWEEN ANATOMICAL VARIATIONS IN THE ARTERIAL CIRCLE OF WILLIS AND STROKE

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Abstract: **Objectives:** Review the anatomy of the Arterial Circle of Willis (CoW), highlighting its main anatomical variations and relating them to possible pathophysiological changes capable of increasing the incidence of Cerebral Vascular Accidents (CVA) in the general population. **Methods:** An anatomical, pathophysiological and epidemiological literature review was carried out in the Pubmed, Scielo and Google Scholar databases, using the descriptors: “Circle of Willis”, “Anatomical variations” and “Cerebrovascular accident”. The classic anatomy of CoW was addressed, also covering the main variations in the vascularization of the skull base and the related epidemiological and pathophysiological aspects, with emphasis on the possibility of increased risks of strokes. **Results:** Given the potential function of CoW in maintaining adequate blood flow, in the face of processes that compromise cerebral irrigation, the association between some local anatomical variants and the development of an efficient collateral circulation demonstrated to reduce the risks of transient ischemic attack and strokes Brain, when compared to the risks of these events for patients without the development of these collaterals. Furthermore, most cases describe hypoplasia of the posterior communicating artery (PCA) as the main variation found in CoW, with its smaller diameter associated with an increased chance of ischemic events. The reported prevalence range of AcoP hypoplasia was 8% to 28.7%. Also noteworthy is the association between the persistence of fetal arterial segments related to the poor development of compensatory collateral circulation in occlusive conditions, which favors the outcome of strokes. **Conclusions:** There is evidence that variations in the classic morphology of CoW can generate varied clinical repercussions, with emphasis on cases of arterial hypoplasia and persistence of fetal vessels in adult

individuals, with such variations being associated with the poor development of compensatory collateral circulation in occlusive conditions, leading to extensive deficits in ischemic conditions. This way, detailed anatomical knowledge correlated with the understanding of cerebral hemodynamics may help to elucidate questions still present in the scientific community regarding various clinical syndromes, offering the possibility of safer endovascular interventions and open neurosurgical procedures. This makes it possible to offer a more favorable prognosis to patients at increased risk of stroke.

INTRODUCTION

The Circle of Willis (CoW) is a complex of arterial anastomoses that connects the anterior and posterior circulations, and that of both cerebral hemispheres, ensuring efficient cerebral hemodynamics. Its completeness and permeability are essential to ensure cerebral blood flow. The typical anatomy of textbooks is characterized by a symmetrical polygon composed of an anterior and a posterior circulation (DE CARO, 2021), connected by communicating arteries, composing a set composed of the six main cerebral arteries, the internal carotid arteries and, also, the basilar artery (MUKHERJEE, 2018; MACHADO, 2007). The anatomy of the cerebral arteries has considerable morphological variation in the general population, and a complete CoW is present in less than 50% of people (DE CARO, 2021). The most common variations include incomplete development (hypoplasia) and absence (aplasia) of arterial segments (WESTPHAL, 2021). Only around 20% of individuals included in anatomical studies have the complete structure, with the absence of hypoplastic segments (SHAHAN, 2017).

Anatomically, the anterior part of the CoW is constituted by the anterior cerebral artery (ACA) on both sides. Furthermore,

the anterior communicating artery joins the right and left ACAs. In the dorsal part of the CoW, the unpaired basilar artery divides into right and left posterior cerebral arteries (PCAs), each of which connects to the ipsilateral internal carotid artery via the posterior communicating arteries. The ACAs and middle cerebral arteries supply more than 80% of the brain, while the remainder of the supply is provided by the PCAs (OUMER, 2021).

CoW variations are clinically important due to their essential role in cerebral hemodynamics as a collateral anastomotic network. In patients with an intact CoW but progressive atherosclerotic cerebrovascular disease, collateral circulation through the Circle is provided by the anterior (ACA) and posterior (PCA) communicating arteries. People with effective collateral circulations have a lower risk of developing a stroke compared to those with ineffective collateral circulations (WESTPHAL, 2021). In individuals with atherosclerotic disease and without previous vascular events, the anterior region of incomplete CoW is associated with a greater risk of BRAIN VASCULAR ACCIDENTS in the anterior circulation, and an even more significant risk in people with combined anterior and posterior variations, this is because the plaques atherosclerotic cells tend to accumulate in arterial trunks, curvatures and bifurcations (WANG, 2023).

The CoW connects the three largest brain territories (right and left anterior, and posterior). Therefore, the classification of brain injuries caused by vascular events benefits if variations in CoW are considered, and not just brain mapping through imaging exams (RANGUS, 2022).

Although there are studies on variations in the anatomy of the Circle of Willis, it is not clear whether the presence of variations is associated with BRAIN ACCIDENTS, in a

similar way, in studies from different regions of the world (OUMER, 2021). In any case, it is clear that altered flow patterns and high collateral flow rates are found near occlusions in many cases of STROKE ACCIDENTS (CHIEN, 2017). Currently, problems related to cerebrovascular diseases are increasing, and BRAIN ACCIDENTS are the fourth leading cause of death and the most common event of loss of autonomy and quality of life (HAMMING, 2019). Therefore, evidence is needed on the combined measure of association between the presence of anatomical variations in the Willis anastomotic complex and the predisposition to stroke (OUMER, 2021). Therefore, the present study aimed to determine whether there is an association between anatomical variations in the Circle of Willis and BRAIN STROKE ACCIDENTS, combining the available studies.

METHOD

For the bibliographic review, articles were consulted in the PubMed, SciELO and Google Scholar databases, by crossing the following descriptors: "Circle of Willis", "Anatomical variations" and "Stroke". Articles published in the last 120 months were selected, that is, from 2013 to 2023. Therefore, retrospective studies, original articles, qualitative and quantitative research, review articles on the topic and case studies were included. The research was carried out in two phases: (1) screening of titles and abstracts: in this phase, articles that did not fit the topic covered were excluded; (2) after screening the titles and abstracts, it was verified that the articles were duplicated in the database selections, that is, if two identical articles were selected from different databases. After these two steps, the selected articles were read completely to create this review.

RESULTS

A total of 16 articles were selected to construct this integrative review. In the PubMed database, 616 articles were captured. In the first phase of the research, 602 articles were excluded because they did not fit the theme of this study. 14 articles were used in this research. 1 article used in the research was selected from Google Scholar. The others were excluded due to duplication or for not covering the proposed topic. In the SciELO database, 1 article was found in the intersection of the descriptors "Willis" and "Stroke", which was used, and its theme referred to the association between CoW and the risk of STROKE ACCIDENTS in patients with carotid artery disease (Table 1).

Among the articles selected for full reading, the main themes found were the association between the anatomical variation in CoW and Ischemic Stroke, as well as its impact; and changes and/or occlusion in the fetal posterior cerebral artery (Chart 1).

Studies on anatomical variations in CoW have identified that this complete anastomotic network is present in less than 50% of people (DE CARO, 2021). One of them also showed that only 20% of the individuals analyzed had a complete anastomotic network and no hypoplasias (SHAHAN, 2017).

An original article, published in the journal *Saúde e Ciência*, mentions that the most common variation of the posterior communicating artery would be fetal CoP (hyperplastic), described in most cases, followed by hypoplastic CoP (SHABAN, 2013; SADEH-GONIK, 2023; PEIXOTO, 2015). Furthermore, the presence of fetal AcoP is related to the mechanisms of BRAIN VASCULAR ACCIDENTS, its location and pattern of infarction, mainly due to the difference in hemodynamic status caused by the presence or absence of this variation (RYU, 2022).

In a study published in BMC Neuroscience in 2021, it was reported that the existence of any variation in CoW represents a 1.38 greater probability of developing stroke when compared to patent CoW. This same study also mentions that, in addition to ACoP hypoplasia, the presence of a smaller diameter of the Anterior Communicating Artery is also a contributing factor (OUMER, 2021).

The importance of CoW integrity for collateral flow in cases of stroke was demonstrated, helping to provide more favorable prognoses, also claiming that the larger the affected territory, the more severe cerebrovascular accidents the result will be (SABLIW, 2023;ŠIRVINSKAS, 2023;). Furthermore, it is identified that an incomplete anterior circulation, added to the presence of an also incomplete posterior circulation, is related to the existence of a future STROKE ACCIDENTS in the anterior circulation (VAN SEETERS, 2015).

DISCUSSION

The importance of CoW integrity for maintaining hemodynamics and brain function is unquestionable. Its collateral pathways play an essential role, serving as a shortcut for blood flow, especially in cases where the main bed is compromised, as occurs in atherosclerotic disease or BRAIN STROKE ACCIDENTS (SADEH-GONIK, 2023).

There was a consensus that the anatomical variations of CoW and its collateral potential contribute to a lower risk of strokes. Although the number of specific studies on the topic is small, in practically all of them common points were found, such as the description of the classic morphology of CoW, the existence and types of variations, the chance of occurrence of BRAIN STROKE ACCIDENTS in individuals with inefficient or non-existent collateral circulation, and also the repercussions of BRAIN STROKE ACCIDENTS on affected

patients.

The articles highlight the importance of identifying and differentiating anatomical variations in this brain anastomotic network, to better understand and manage their vast clinical repercussions. Among the variations described, the following stand out: hyperplastic fetal CoP (main variation of the posterior communicating artery) followed by hypoplastic CoP and, also, the reduction in the diameter of the anterior communicating artery. All the consequences of the existence of these variations can imply different outcomes, favorable or unfavorable, depending on specific scenarios, which were illustrated by some of the articles used.

In an attempt to understand this phenomenon and evaluate appropriate interventions, several of the studies cited in the present study relate CoW and possible cases of its involvement, such as atherosclerotic cerebrovascular disease and BRAIN VASCULAR ACCIDENTS.

This association is used to point out the role of variations in the collateral arrangement of blood flow, especially in healthy individuals, without previous cerebrovascular events. However, it is important to highlight the need for more research on the association between variations in CoW and the outcome of BRAIN ACCIDENTS to be carried out in order to evaluate this correlation in more depth.

CONCLUSION

The studies found show that CoW variations are clinically important due to their essential role in cerebral hemodynamics as a collateral anastomotic network.

Some studies show that people with effective collateral circulations have a lower risk of developing STROKE ACCIDENTS, compared to those with ineffective collateral circulations. In individuals with atherosclerotic disease and without previous

| | Total articles captured | 1st stage: exclusion by title and abstract | 2nd stage: exclusion due to duplication | 3rd stage: read in full | Selected articles |
|----------------|-------------------------|--|---|-------------------------|-------------------|
| Pubmed | 616 | 601 | 1 | 14 | 14 |
| SciELO | 1 | 0 | 0 | 1 | 1 |
| Google Scholar | 135 | 134 | 0 | 1 | 1 |

Table 1: Results of article selection by stages:

| Job title | Authors | Year | Country | Design |
|---|----------------------------|------|-------------|------------------------------|
| Variants of the circle of Willis in ischemic stroke patients | From Dear J, | 2021 | Germany | Original article |
| Association between circle of Willis and ischemic stroke: a systematic review and meta-analysis | Oumer M | 2021 | Ethiopia | Systematic literature review |
| Circle of Willis Configuration and Thrombus Localization Impact on Ischemic Stroke Patient Outcomes: A Systematic Review. | Širvinskas A, | 2023 | Lithuania | Systematic literature review |
| Circle of Willis variations in migraine patients with ischemic stroke | Hamming AM | 2019 | Netherlands | Original article |
| Reclassifications of ischemic stroke patterns due to variants of the Circle of Willis | Rangus I, | 2022 | Germany | Original article |
| Impact of circle of Willis anatomy in traumatic blunt cerebrovascular injury-related stroke | Shahan CP, | 2017 | U. S | Original article |
| Circle of Willis variants and their association with outcome in patients with middle cerebral artery-M1-occlusion stroke | Westphal LP, | 2021 | Switzerland | Original article |
| Analyzing Circle of Willis blood flow in ischemic stroke patients through 3D Stroke Arterial Flow Estimation | Chien A, | 2017 | U. S | Original article |
| Completeness of the circle of Willis and risk of ischemic stroke in patients without cerebrovascular disease | Van Seeters T | 2015 | Netherlands | Original article |
| The incomplete circle of Willis is associated with vulnerable intracranial plaque features and acute ischemic stroke. | Wang H | 2023 | China | Original article |
| The Presence of Communicating Arteries in the Circle of Willis Is Associated with Higher Rate of Functional Recovery after Anterior Circulation Ischemic Stroke | Sablić | 2023 | Croatia | Original article |
| A Patient-Specific Simulation Based Study | Mukherjee D | 2018 | U. S | Original article |
| Mechanisms of Stroke in Patients with Fetal Posterior Cerebral Artery. | Ryu JC | 2022 | Amsterdam | Original article |
| Circle of Willis Variants: Fetal PCA. stroke | Shaban A, | 2013 | U. S | Systematic literature review |
| Circle of Willis integrity in acute middle cerebral artery occlusion: does the posterior communicating artery matter? | Sadeh-Gonik U | 2023 | Israel | Original article |
| Anatomical variations in the posterior portion of the circle of Willis | PEIXOTO, Raiza Luna et al. | 2015 | Brazil | Original article |

Table 1: Articles captured for the literature review

vascular events, the incomplete anterior region of CoW is associated with a greater risk of BRAIN VASCULAR ACCIDENTS in the anterior circulation, and an even greater risk in people with combined anterior and posterior variations.

In general, therefore, research indicates that there is evidence that variations in the classic morphology of CoW can generate varied clinical repercussions, with such variations being associated with the poor development of a compensatory collateral circulation in occlusive conditions, leading to extensive

deficits in ischemic conditions.

However, there are still few studies that address the topic in question, making more population-based research necessary to define the real prevalence of each anatomical variation, as well as studying their relationship with the incidence of strokes, in order to assist in elucidating questions still present in the scientific community regarding the topic, offering the possibility of safer neurosurgical interventions and procedures, in addition to enabling a more favorable prognosis for patients at increased risk of stroke.

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