Section: Anatomy

Original Research Article

INCIDENCE OF MORPHOLOGICAL VARIATIONS IN CIRCLE OF WILLIS – AN ANATOMICAL AND RADIOLOGICAL ASSESSMENT

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Received : 22/06/2023
Received in revised form : 31/07/2023
Accepted : 13/08/2023

Keywords:
Circle of willis, brain specimen, MRI, anatomical variations.

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DOI: 10.47009/jamp.2023.5.4.322

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2023; 5 (4); 1618-1622

Abstract

Background: The architecture of Circle of Willis and its potential variations must be thoroughly understood by clinicians, vascular surgeons, and radiologists. By examining the brain samples as well as utilising cutting-edge diagnostic and therapeutic methods, this can be accomplished. As a result, the aim of this study was to explore the morphological and radiological features of standard pattern and variantions of Circle of Willis. **Materials and Methods:** Fifty embalmed brain specimens of different sexes and ages was carried out in Department of Anatomy between 2015 and 2017. The radiological investigation was conducted concurrently at Stanley Medical College and Hospital's Department of Radiodiagnosis among 50 healthy people’s magnetic resonance angiography pictures. **Results:** The percentage of abnormal circles in all brain specimens was 42%, while the percentage of abnormal circles in all radiographic and MRI findings were 32%. While abnormal anterior and posterior circles were seen on brain material in 14% and 28% of patients respectively, abnormal anterior and posterior circles were visible on the MRI in 14% and 18% of instances. The hypoplasia that was more frequently seen in posterior communicating artery than posterior cerebral artery was the most frequent difference among those found. **Conclusion:** The basic architecture of Circle of Willis and its variations such as hypoplasia, attenuation of arteriesand anomalous origin must be fully understood by all practitioners. This will help them to identify the illnesses, plan for continuous management and enabling them to carry out appropriate interventional operations.

INTRODUCTION

The brain is a crucial organ that needs a plentiful blood flow to maintain its continuing functions. When the blood supply is cut off for a short period of time, irreversible brain damage ensues and a person loses consciousness.[1] The adult brain uses about 20% of the oxygen available, yet only about 15% of the blood flow overall reaches it.[2] It is estimated that the brain tissue receives about 800 cc of blood every minute. White matter has a lower blood flow rate (30ml/100g/min) than grey matter (70-80ml/100g/min). Less than 15 ml/100 g/min of blood flow causes irreversible brain damage.[3]

Four arterial trunks, including two vertebral arteries and two internal carotid arteries, supply the brain with blood. At the level of the upper thyroid cartilage border, the internal carotid artery splits off from the common carotid artery. The vertebral artery is a branch of the subclavian artery's first segment.[4]

The internal carotid artery and vertebral artery are joined by a significant arterial anastomosis called the Circle of Willis. It has the name of English doctor Thomas Willis.[5,6] Both arteries and their branches are located in the interpeduncular cistern, a subarachnoid area at the base of the brain. It is a network of blood arteries that resembles a ring and is crucial for the perfusion of the brain. The two vertebral arteries provide 20% of the blood supply to the brain, while the two internal carotid arteries provide 80%.[7] The anterior and middle cerebral arteries, which provide blood to the brain, are formed by the branches of each internal carotid artery. The connecting arteries that join the circle's anterior and posterior portions complete the ring.

Anatomical changes in the Circle of Willis can be observed in roughly 60% of cases.[8,9]

The Circle of Willis is made up of the anterior communicating artery and the posterior communicating arteries, which are referred to as the main collateral channels. Secondary collaterals include additional channels include flow reversal through the anterior choroidal artery, ophthalmic artery, and the junction between the cortical branching of the intracerebral arteries.[10] These collaterals turn into the primary anastomotic channels in the event of a Willis Circle anomaly. The existence and size of its component vessels affect the Circle of Willis' collaterals.[11]

The connecting arteries barely have any blood flow when things are normal. The flow can be shifted to perfuse the depleted brain areas if an individual has an anatomically abnormal circle or is suffering from a pathological condition.[12] The Circle of Willis is frequently absent or undeveloped in 50% of the normal brain and 80% of the diseased brain, according to research. The absence of vessels, hypoplastic vessels, and additional vessels are the most prevalent morphological variations.[1] These differences may make it more difficult for people with atherosclerosis to sustain blood flow through their arterioles, which raises their risk of stroke and transient ischemic attack.[3] In patients with an incomplete Circle of Willis.[13] acute embolization from a stenosis of any artery can lead to occlusion, as can chronic embolization from stenosis of any channel. Given that stroke is one of the primary causes of morbidity and mortality in the elderly, these issues are important.

Clinicians, vascular surgeons, and radiologists must have a thorough understanding of the anatomy of the Circle of Willis and any potential deviations. This will aid them in comprehending the majority of cerebrovascular illnesses, performing modern diagnostic and therapeutic techniques, and deciphering images obtained through Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI).[14] Therefore, the goal of this study was to investigate the morphological and radiological aspects of the typical pattern and variations of the Circle of Willis.

MATERIALS AND METHODS

In the Department of Anatomy at Stanley Medical College, this study was conducted on 50 preserved human cadavers of all sexes and ages. Between 2015 and 2017, researchers dissected and examined the brain samples. 50 embalmed adult human brain specimens were gathered in order to evaluate the anomalies of the brain tissue. From 2015 to 2017, the radiological investigation was carried out at the Stanley Medical College and Hospital's Department of Radiology. A total of 50 magnetic resonance angiogram images were taken for the study with the required informed consent from each individual from the patients who were participating in the study and were visiting the hospital for a health checkup. Prior to the start of the investigation, approval from the institutional ethical committee was obtained.

Dissection method

After putting a pencil line on the skull no higher than one centimetre above the orbital borders and the external occipital protuberance, the skull cap was removed. The skull's vault was opened along the drawn line using a chisel and hammer, and the skull cap was then taken off. By carefully cutting the cranial nerves near their departure through the numerous foramina, the meninges are reflected, the brain is removed, and the spinal cord is disconnected from it below the level of the medulla oblongata. The internal carotid arteries, basilar artery, and vertebral arteries are all tracked. The interpeduncular cisterns at the base of the brain are then opened, revealing the Circle of Willis. For 10 days, 10% formalin was used to preserve the base of the brain, including the brainstem with an intact arterial circle. The main branches of the Circle of Willis were dissected in detail. The Circle of Willis and its variations were photographed and recorded.

The interpeduncular cistern at the base of the brain contains The Circle of Willis. The Circle of Willis connects the internal carotid and vertebrobasilar arteries to the brain and is a significant collateral blood vessel. The diameter of the vessels was measured using a calliper with a graduated range of up to 0.02mm. Hypoplastic arteries were those with a diameter of less than 1 mm for cerebral vessels and less than 0.5 mm for connecting arteries15.

Radiological method

Three Dimensional Time of Flight Magnetic Resonance Angiography (3D-TOF-MRA) was the method and 1.5Tesla MRI scanners were employed. Only the arteries that make up the Circle of Willis were used for the investigation. The imaging parameters that were used were as follows: repetition time/echo time 23/7.0, flip angle 25 degrees, slice thickness 0.7mm, number of slices per slab 44, number of slabs 4, slice overlap 25%, flow direction feet to head with 40mm saturation at the head end, field of view 180x158, and 256 matrix size16. The Circle of Willis is split into anterior and posterior configurations for identification purposes.

The Circle of Willis parameters like Forming fully or partially, shape, caliber, standard or unusual, asymmetry or symmetry in the pattern, researchers looked into morphological differences such as nonexistent vessels, attenuation, duplication and triplication, and aberrant origin. All these parameters were noted in this investigation using both radiological and dissection techniques. Microsoft Excel was used to enter the data and perform the descriptive statistical analysis.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

RESULTS

Overall proportion of brain specimens with anomalous circles were 21 (42%) and the overall radiological - MRI findings with abnormal circles were 16 (32%), in this study. Brain specimen showed abnormal anterior and posterior circle in 14% and 28% of cases, respectively however the MRI showed abnormal anterior and posterior circle in 14% and 18% of cases, respectively. (Table 1).

Table 1: Incidence of variation in circle of Willis

Incidence of variation in circles	Frequency	Percentage
In Specimens		
Anterior circle	07	14
Posterior circle	14	28
In Radiological findings (MRI)		
Anterior circle	07	14
Posterior circle	09	18

On assessing the proportion of vessels with specific abnormalities in dissected brain Specimens, anterior cerebral artery was found to have 4% abnormalities, anterior circulating artery and posterior cerebral artery had 10% abnormalities, each and posterior circulating artery had 18% abnormalities. The proportion of vessels with specific abnormalities in dissected brain Specimens is shown in table 2.

Table 2: Proportion of vessels with specific abnormalities in dissected brain Specimens

Name of the vessel	Absent vessel	Hypo plastic vessel	Accessory vessels	Anomalous vessels	Total
Anterior cerebral artery	00	01 (2)	01 (2)	00	02 (4)
Anterior circulating artery	00	01 (2)	04 (8)	00	05 (10)
Posterior cerebral artery	00	03 (6)	00	02 (4)	05 (10)
Posterior circulating artery	01 (2)	08 (16)	00	00	09 (18)
Total	01 (2)	13 (26)	05 (10)	02 (4)	21 (42)

On assessing the proportion of vessels with specific abnormalities in MRI, anterior cerebral artery was found to have 14% abnormalities, anterior circulating artery had no abnormalities, and posterior cerebral artery had 16% abnormalities and posterior circulating artery had 2% abnormalities. The proportion of vessels with specific abnormalities in MRI is shown in table 3.

Table 3: Proportion of vessels with specific abnormalities in MRI

Name of the vessel	Absent vessel	Hypo plastic vessel	Accessory vessels	Anomalous vessels	Total
Anterior cerebral artery	00	07 (14)	00	00	07 (14)
Anterior circulating artery	00	00	00	00	00
Posterior cerebral artery	00	04 (08)	00	04 (08)	08 (16)
Posterior circulating artery	00	01 (02)	00	00	01 (02)
Total	00	12 (24)	00	04 (08)	16 (32)

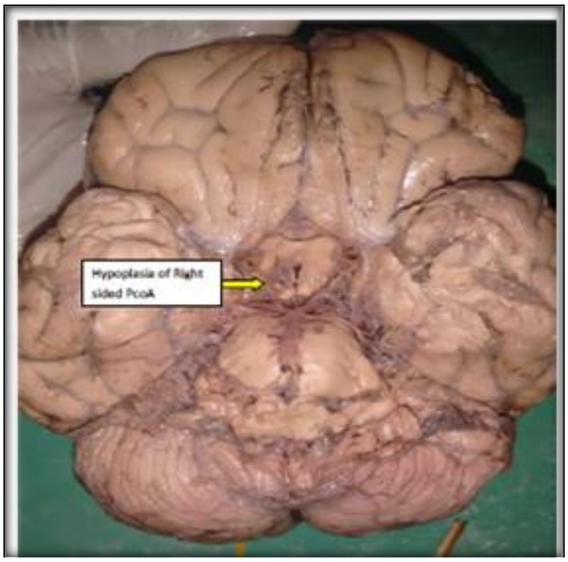

Figure 1: Hypoplasia of Posterior Communicating artery

Figure 2: Hypoplasia of Left posterior Cerebral Artery

ISSN (O): 2687-5365; ISSN (P): 2753-6556

DISCUSSION

There are numerous variations that can be applied to the Circle of Willis and its branches. The variances can be seen not just on the same person's right and left sides, but also from person to person. Due to the equalisation of blood pressure caused by the arterial circle, there is little blood exchange along the anastomotic channel under normal circumstances. The arterial circle tends to equalise pressure in occlusion cases, maintaining circulation. From 5% to 72% of polygons have the conventional circle shape that is "standard text book type".[11] The vast range of difference is brought on by the variety in how hypoplastic vascular definition criteria are made.

Shirol VS et al.[17] examined 50 adult brain specimens for morphometric variance in the Circle of Willis. Out of the 50 specimens, 28 cases (or 56%) of the Circle of Willis had a typical pattern, whereas 22 cases (or 44%) displayed variances. The hypoplastic posterior communicating artery, with a proportion of 31.8%, is the most frequently documented variation. Seven abnormalities in the anterior circulation and fifteen changes in the posterior circulation were found among the 22 cases. In this study, differences in the anterior circle were detected in 7 cases, whereas variations in the posterior circle were found in 14 cases. The results of the current study agreed with those of Riggs HE et al.[13] Alpers BJ et al.[13] Dimmick SJ et al.[18] and Kamath S et al.[19] investigations as well.

Iqbal S et al's.[11] study conducted on the adult human brain's anatomical variance of the Circle of Willis included the morphological differences of the arteries that make up the Circle of Willis. The bulk of the circles in their analysis (52%) exhibited variances. The most frequent alteration, hypoplasia, was seen in 24% of the brain samples. In 12% of the circle, there were accessory arteries in the form of triplets or duplications of the anterior communicating artery. 42% of the brain samples used in this investigation displayed variance. The criteria include the circle's completeness, symmetry, normal calibre, and polygonal shape. Comparable to the earlier study conducted by Iqbal S et al.[11] hypoplasia was a frequent variant seen in 26% of the participants in the current study.

It was discovered that among the variants, hypoplasia or attenuation of either the cerebral or the connecting vessel was typical. In the current study, 26% of the participants had hypoplasias, which were prevalent in all other variants. Alpers BJ et al.[13] reported a 27% incidence of hypoplasia, Kamath S et al.[19] a 24% incidence, and Fetterman GH et al.[20] a 23% incidence.

The Circle of Willis contained accessory vessels in the form of duplication or triplication. There were five instances of duplication of the anterior communicating artery and 4.7% of the anterior cerebral artery among the auxiliary arteries. In the posterior circulation, the auxiliary vessels were not noticeable. These findings were in line with those of Iqbal S et al.[11] and showed that there are three anterior cerebral arteries in addition to the two typical ones.

The lack of one of the cerebral or connecting vessels was the least frequent aberration of the Circle of Willis. In the current study, a percentage of 4.7% of cases had no posterior connecting artery. The incidence of missing vessels in the Circle of Willis in healthy brains has been observed to range from 0.6%13 to 17%.[21] The anterior portion of the circle does not contain the missing vascular. 3.8% of posterior connecting artery missing vessels were found, according to Fawcett E et al.[22]

The changes in the structural pattern of the Circle of Willis influence the signs and symptoms of cerebral vascular disorders such stroke, thromboembolism, and aneurysms. The communicating arteries carry the majority of the collateral blood flow, and the degree of hemodynamic impairment depends on the obstruction of the collateral pathway.[23] Determining the effectiveness of the brain circulation depends on the status of the circle.

Using Magnetic Resonance Angiography, which was used for the radiological research, 34 cases were found to be normal, while the remaining 16 cases displayed an aberrant form of Circle of Willis. The aberrant circle had an incomplete, uneven, or abnormally large design. The Circle of Willis-specific changes were taken and observed in 16 cases. Due to the study's purpose, other variants that were present were not considered. These changes consist of vertebral hypoplasia, internal carotid artery stenosis or narrowing, internal carotid artery ectasia, and vertebrobasilar fenestrations. Whether or whether there is collateral flow affects how the neurovascular damage turns out. The availability of these collaterals is based on the typical Circle of Willis pattern.[19] The veins that make up the Circle of Willis determine how well blood flow is distributed.[24]

Radiologically, the frequency of the Circle of Willis normal pattern varies greatly between investigations. Out of 50 radiological images included in the study, 16 instances (32% of all cases) displayed variations in the Circle of Willis pattern. However, Krabbe Hartkamp MJ et al.[25] and Haripriya M et al.[26] reported the same as 42% and 32%, respectively.

CONCLUSION

The posterior cerebral artery and posterior communicating artery were discovered to vary more in the posterior half of the circle (66.7%) than in the anterior section of the circle (33.3%). The most frequent difference among those discovered was hypoplasia, which was more frequently observed in the posterior communicating artery than the posterior cerebral artery. Clinicians, neurosurgeons, vascular surgeons, and radiologists must have a good understanding of the typical architecture of the Circle of Willis as well as its variants, such as hypoplasia, attenuation of arteries, and anomalous origin. They can use this to diagnose the illnesses and make plans for ongoing management so that the right interventional procedures can be carried out.

Declarations

Ethical Approval

Obtained Ethical Approval for this study from Institutional Ethical Committee, Government Stanley Medical College, Chennai.

(IEC meeting held on 14.06.2016 at the Council Hall, Stanley Medical College, Chennai)

Competing Interests: NIL

Authors Contributions

1. Shanthi: Project development, Data collection, Data analysis & Manuscript writing
2. Senthilkumar: Data collection, Data analysis & Manuscript writing
3. Kannan: Data analysis & Manuscript writing
4. Subbulakshmi: Data analysis & Manuscript writing

Funding: Nil

Availability of Data and Materials: not applicable.

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