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Research Article

CIRCLE OF WILLIS AND ITS VARIATIONS; MORPHOMETRIC STUDY IN ADULT HUMAN CADAVERS

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ABSTRACT

Background and Objectives: Circle of Willis plays a vital role in collateral circulation and redistribution of blood to all areas of the brain. Variation in circle of Willis is known to cause grave disorders like cerebrovascular disorders, subarachnoid haemorrhage, cerebral aneurysm and schizophrenia. The objectives of the present study are to study the formation and branching pattern of circle of Willis and also to study the distribution of variations. **MATERIALS & Methods:** The study was conducted on 50 adult brain specimens. Each brain was removed in one piece by dissection and the circle of Willis was observed for its formation, pattern and variations. **Results:** Among the 50 specimens studied, 28 cases (56%) had a normal pattern of circle of Willis and variations were observed in the remaining 22 cases (44%). More number of variations was observed on the right side than on the left side. The most common variation observed was hypoplastic posterior communicating artery (7 cases, 31.8%). Posterior communicating artery was found to be the most variable vessel while middle cerebral artery was the least variable vessel. **Interpretation and Conclusion:** The results with respect to the circle of Willis and all its component arteries were consistent with the results in the available literature. The only exception was the increased incidence of absence of both the anterior and posterior communicating arteries. This finding is of clinical significance to neurologists and neurosurgeons in this geographical location of north Karnataka. A higher incidence of variations in the communicating arteries is likely to manifest as a higher incidence in disorders like migraine, schizophrenia and cerebrovascular disorders due to compromised collateral circulation and poor redistribution of blood.

Keywords: Circle of Willis, Anterior Cerebral Artery; Middle Cerebral Artery; Posterior Cerebral Artery; Anterior Communicating Artery; Posterior Communicating Artery

INTRODUCTION

Circle of Willis is the arterial anastomosis at the base of the brain which is also referred as “Circulus Arteriosus cerebri”. The pattern of arterial arrangement & communication forms a unique arterial network connecting the principle arteries supplying the brain.[1]

Circle of Willis was named after a popular British Anatomist-Physician Thomas Willis (1621-1673) who was the first to describe it completely[2]. Though called a circle, it is precisely a nonagon or a nine sided polygon[3]. The circle of Willis is a large arterial anastomosis which unites the internal carotid and vertebro-basilar systems. It lies in the subarachnoid

space within the interpeduncular cistern, and surrounds the optic chiasma and infundibulum. Anteriorly, the anterior cerebral arteries, derived from the internal carotid arteries, are linked by the small anterior communicating artery. Posteriorly, the two posterior cerebral arteries, formed by the bifurcation of the basilar artery, are joined to the ipsilateral internal carotid artery by a posterior communicating artery.[4, 5]

There is considerable individual variation in the pattern and caliber of vessels that make up the circulus arteriosus. Although a complete circular channel almost always exists, one vessel is usually sufficiently narrowed to reduce its role as a collateral route and the circle is rarely functionally complete. The haemodynamics of the circle are influenced by variations in the caliber of communicating arteries and in the segments of the anterior and posterior cerebral arteries which lie between their origins and their junctions with the corresponding communicating arteries. The greatest variation in caliber between individuals occurs in the posterior communicating artery, which is normally very small, so that only limited flow is possible between the anterior and posterior circulations.[1]

Brain depends on continuous and uninterrupted supply of blood as its source for oxygen, glucose and other nutrients for its normal functioning. The rapidity of unconsciousness in common syncope, more traumatically induced but mercifully swift in judicial hanging, are dramatic reminders of the precarious aerobic balance in which the parenchyma of the brain survives[6].

It is a well established fact that the adequacy and compliance of collateral circulation plays a vital role in the course and severity of a cerebrovascular disorder. Analysis and establishing the pattern of circle of Willis is one of the most important prerequisites of various diagnostic & therapeutic neurovascular procedures. In case of complete unilateral vascular occlusion or thrombosis, expansion of anastomotic channels and collateral circulation in circle of Willis is life saving[8.]

Aneurysms are balloon-like swellings which occur on as a result of defects in the arterial wall. They are most commonly found on the vessels of the circle of Willis particularly at or near the junctions of vessels.

The normal pattern of circle of Willis is relatively uncommon. Various studies in the past have revealed that a significant lack of consistency exists in the pattern and branching of circle of Willis. Circle of Willis shows a considerable degree of individual variation which may justify the fact that, its functional efficiency differs widely in different individuals.

All these facts put together makes this present study all the more interesting and important. The present study is an effort to gather a substantial knowledge and information about the variations in circle of Willis in population of North Karnataka.

MATERIAS & METHODS

The present study is based on 50 adult brains dissected from embalmed cadavers in Department of Anatomy, Jawaharlal Nehru Medical College, Belgaum. Each brain was removed in one piece by dissection. Only complete and intact specimens were used for the study. Observations were made in 50 such specimens were later preserved in 10% formalin solution. Each circle was examined in the intact brain and a drawing was made. After removing the meninges carefully from the base of the brain, the circle of Willis was observed in situ and a detailed study of the circle and associated arteries was made. The findings were noted and tabulated. The arteries and the circles were studied under the following parameters:

1. Origin of cerebral and communicating arteries.
2. Branching pattern of cerebral and communicating arteries.
3. Position and course of the above arteries.
4. Shape of the arterial circle.
5. Abnormalities if any.

A thorough search was again made for any variations in the cerebral arteries, their branches and communicating arteries. A search was also made for aneurismal dilatations under magnification. A magnifying lens was used whenever required. High resolution photographs were taken using Nikon 8.0 megapixel digital camera with 3X optical magnification at various convenient angles.

RESULTS

Among the 50 specimens of circle of Willis dissected and observed in the present study, typical description of normal circle was seen in 28 cases (56%). Variations were found in the remaining 22 cases (44%).

Of the 22 variations seen, 7 variations (31.8%) were seen in the anterior circulation and 15 variations (68.2%) were seen in the posterior circulation. More variations were seen on the right side than on the left side. 14 variations (63.6%) were observed on the right side as compared to 5 variations (22.7%) on the left side. 3 variations (13.6%) were seen in the anterior communicating artery.

Anterior cerebral artery variations were seen in 4 cases (18.2%) among the 22 variations found. Hypoplastic (string like) A1 segment (Picture 1) in 3 cases (13.65%). In one case it was on the left side and in two cases on the right side. Hypoplastic (string like) A2 segment was seen in one case (4.55%) on the right side (specimen no. 36). In this case the right cerebral hemisphere was predominantly supplied by branches from an enlarged A2 segment of left anterior cerebral artery.

Among the 22 variations found in the study, 4 variations (18.2%) were seen in posterior cerebral arteries. Absence of P1 segment was seen in one case (4.55%) on the right side. Hypoplastic P1segment (Picture 2) (foetal or embryonic type) was seen in 3 cases (13.65%). On all the 3 occasions the variation was present on the right side. 3 variations (13.6%) were seen in Anterior communicating artery. Complete absence of anterior communicating artery (Picture 3) was seen in 2 cases (9.1%), duplication (Picture 4) was seen in 1 case (4.55%). Highest number of variations was seen to be associated with posterior communicating artery. 11 variations among the 22 variations (50%) were found to be exclusively due to posterior communicating artery. Complete absence and hypoplastic (string like) artery were the variations seen in this artery. 4 cases (18.2%) had complete absence of posterior communicating artery (Picture 5). In 2 cases it was seen on the right side and in 2 cases on the left side. 7 cases (31.8%) had a hypoplastic (string like) posterior communicating artery. In 5 cases it was on the right side (Picture 6). In 2 cases it was seen on the left side. 50% of the variations were seen in the posterior communicating artery. Hence it is the most variable and least consistent vessel in the present study. No aneurysms were seen in any of the arteries in any of the cases. No other unusual or unreported variations were seen in the study sample. No cases had bilateral variations. Double, triple or multiple variations in a single specimen were not seen. Hence, all the variations were singular and no associated variations were found in any specimen.

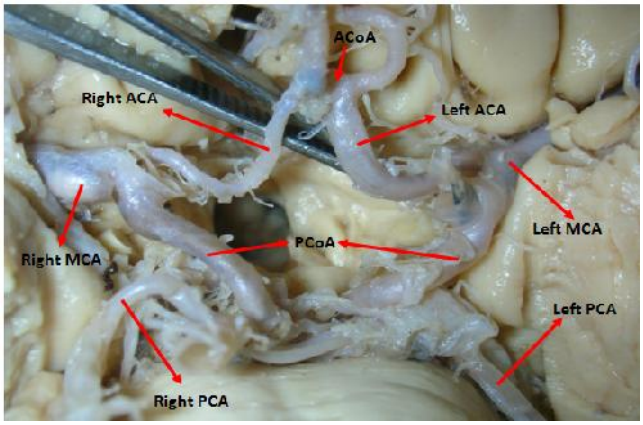

Fig 1: Photograph Showing Hypoplastic A1 segment of Right ACA

ACA – Anterior cerebral artery, AcoA – Anterior communicating artery, MCA – Middle cerebral artery, PcoA – Posterior communicating artery, PCA – Posterior cerebral artery

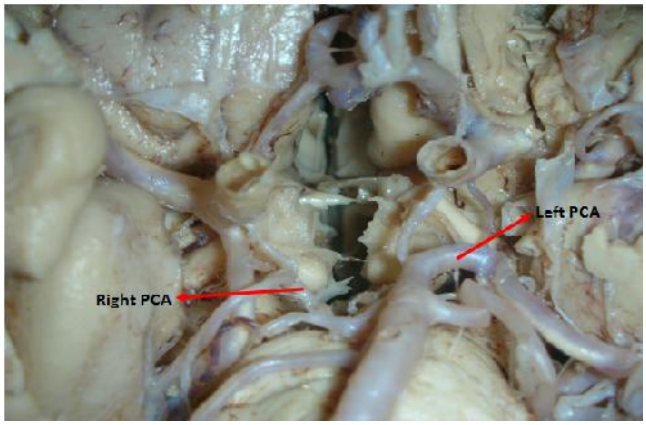

Fig 2: showing Hypoplastic P1 segment of right PCA

P1 - Pre-communicating part of Posterior Cerebral Artery, PCA – Posterior cerebral artery

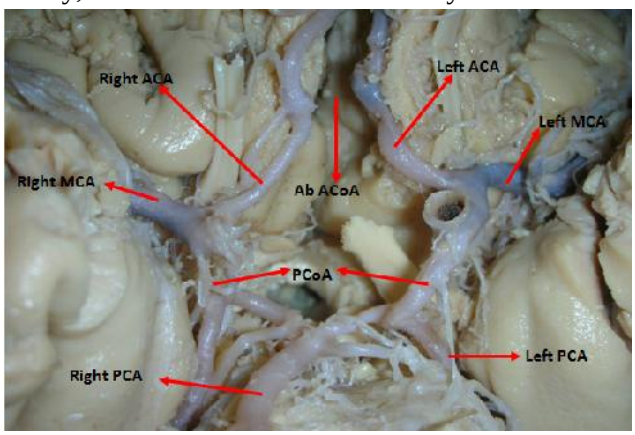

Fig 3: Picture 3: Photograph showing Absence of ACoA

AcoA – Anterior communicating artery, Ab – Absent, PCA – Posterior cerebral artery, ACA- Anterior cerebral artery, MCA- Middle cerebral artery

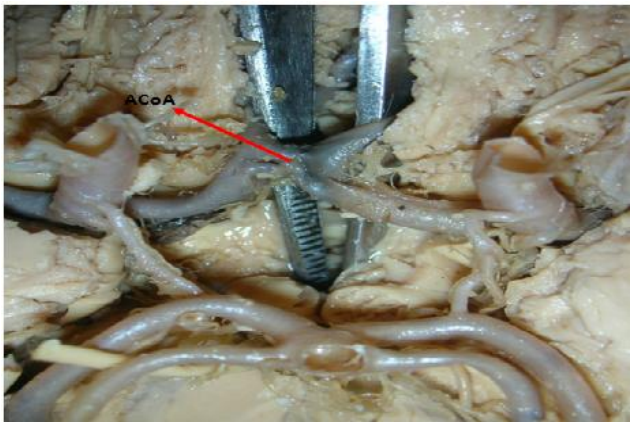

Fig 4: Showing duplication of Anterior communicating artery (AcoA)

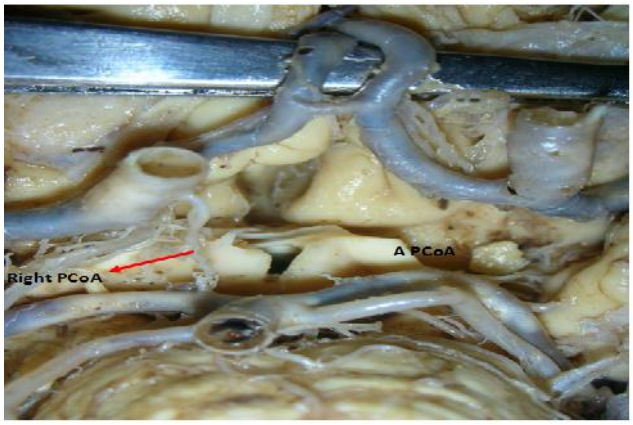

Fig 5: Picture 5: Photograph showing Absence of left PcoA

PcoA – Posterior communicating artery, A - Absent

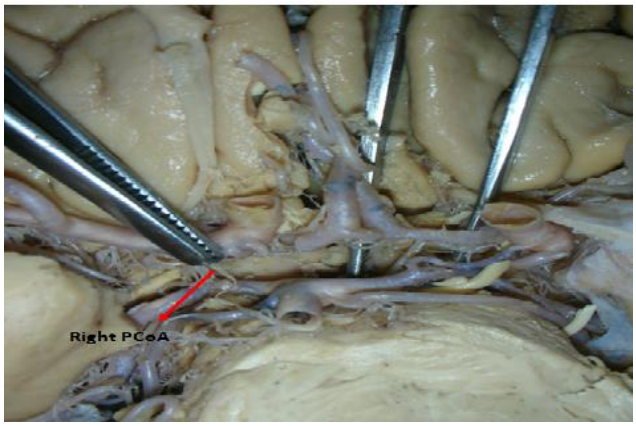

Fig 6: Showing Hypoplastic right Posterior communicating artery (PCoA)

DISCUSSION

The circle of Willis and its branches are subjected to numerous variations. The variations not only differ from person to person but also on the two sides of the same individual. Various dissection and angiographic studies by several workers have shown that variations occur in a very high proportion of cases. Inspite of numerous studies conducted over several decades in several countries employing various methods across different geographical and racial background, there is no clarity as to how and why the variations occur. Different studies have quoted different facts and figures which have led to a spectrum of findings. In the following discussion, findings of the present study have been compared with those of the other authors under each individual constituent artery.

In about one third of all individuals, one of the posterior cerebral arteries arises from the internal carotid artery. Such anomalous condition suggests persistence of embryological origin of the posterior cerebral artery.[4]

Sometimes the anterior communicating artery becomes double, on occasions the proximal part of one of the anterior cerebral arteries is unusually small and in such condition anterior communicating artery assumes a large caliber.[4]

The arterial circle is thought to equalise the blood flow to the different parts of the brain and under normal condition little interchange of blood takes place across anastomotic channel due to equality of blood pressure. However, in case of occlusion of one of the large feeder arteries, the blood crosses the midline through the communicating branches and maintains nutrition of the opposite half of the brain by contra lateral flow.[4]

In the present study, of the 50 brain specimens observed 28 cases (56%) had normal pattern of circle of Willis.

Table 1: Studies on Circle of Willis reported by various authors

Author name	Normal Pattern (%)	Variations (%)
Fawcett and blachford	96.1%	3.9%
Blackburn	29.5%	70.5%
Alpers et al.	52.3%	47.7%
Riggs (1963)	19%	81%
Vare AM & Bansal PC	26.86%	73.14%
Raja Reddy et al.	53.3%	46.7%
Jayasree & Sadasivan	18%	82%
Kamath S	56%	44%
P N Jain and V Kumar	19.45%	80.55%
Stephen and John	52%	48%
Macchi et al.	41%	59%
Hartkamp et al.	42%	58%
Present study	56%	44%

Thus the findings of the present study are approximately similar to the findings of Alpers et al. (1959)[7], Raja Reddy et al. (1972)[8], Kamath S (1981)[9], Stephen and John (1991)[10] with respect to normal pattern of circle. Of the 50 brain specimens observed in the present study, 22 cases (44%) had variations in the pattern of circle of Willis. Thus the findings of the present study are approximately similar to the findings of Alpers et al. (1959)[7], Raja Reddy et al. (1972)[8], Kamath S (1981)[9], Stephen and John (1991)[10] with respect to incidence of variations in the circle.

In the present study, it was observed that variations were approximately twice as common in the posterior circulation (15 cases, 68.2%) as compared to the anterior circulation (7 cases, 31.8%), Similar studies reported by P N Jain and V Kumar (1990)[11] and Hartkamp et al. (1998)[12] with respect to location of variations.

In the present study, hypoplastic A1 segment of anterior cerebral artery was seen in 3 cases (13.65%) among the 22 cases with variations. In 1 case it was on the left side and in 2 cases on the right side. Thus, the findings of the present study are approximately similar to the findings of Lippert (10%) (1985)[13] and Arthur et al. (10.4%) (1996)[14] with respect to hypoplastic A1 segment of anterior cerebral artery.

Hypoplastic A2 segment of anterior cerebral artery was seen on the right side in one case (4.55%) among the 22 cases with variations. The right cerebral hemisphere was predominantly supplied by branches from an enlarged A2 segment of left anterior cerebral artery.

A similar variation where a single median anterior cerebral artery is formed by the joining of both the right and the left anterior cerebral arteries has been reported by Vare A M and Bansal P C (1.7%) (1970)[15], N Jayasree and G Sadasivan (2%) (1981)[16], Kanchan Kapoor (0.9%) (2001)[17].

Hypoplastic P1 segment of posterior cerebral artery was seen in 3 cases (13.65%) among the 22 cases with variations, all on the right side. The findings of the present study are similar to the findings of Alpers et al. (15%) (1959)[7], P N Jain and V Kumar (16%) (1990)[11] and Van overbeeke et al. (14%) (1991)[18] with respect to hypoplastic P1 segment of posterior cerebral artery. Complete absence of P1 segment of posterior cerebral artery on the right side was seen in one case (4.55%). Here the basilar artery continued as the left posterior cerebral artery. The posterior circulation on the right side was maintained by an enlarged right posterior communicating artery. Such absence of P1 segment was reported by Vare A M and Bansal P C (1970)[15] in 19.4% cases.

Duplication of anterior communicating artery was seen in one case (4.5%) among the 22 cases with variations in the present study. Thus, the findings of the present study are approximately similar to the findings reported by Fawcett and blachford (1905)[19] in 7.2% cases, Raja Reddy et al. (1972)[8] in 7% cases and P N Jain and V Kumar (1990)[11] in 5.5% cases, with respect to duplication of anterior communicating artery.

Absence of anterior communicating artery was seen in 2 cases (9.1%) among the 22 cases with variations in the present study. A higher incidence of absence of anterior communicating artery has been observed in the present study in comparison to the results of various other studies.

Absence of posterior communicating artery was seen in 4 cases (18.2%) out of 22 cases with variations, In 2 cases it was seen on the right side and in 2 cases it was seen on the left side. A higher incidence of absence of posterior communicating artery has been observed in the present study as compared to the results of previous studies.Hypoplastic posterior communicating artery was seen in 7 cases (31.8%) among the 22 cases with variations. In 5 cases it was on the right side and in 2 cases it was seen on the left side. The findings of the present study are approximately similar to the findings of Pedroza et al. (34%) (1987)[20]. No variations were observed in the main trunk of middle cerebral artery with respect to the circle of Willis in any of the 50 cases.

Collectively it was observed that the findings of the present study are approximately similar to the results of various other larger and significant studies conducted previously. The only exception being increased incidence of absence of both the anterior and posterior communicating arteries in the present study.

Scope for future work : An exclusive study of the anterior and posterior communicating arteries conducted on a larger sample size and by avoiding the possible confounding factors of age and sex could possibly strengthen the present findings and establish a significant geographical correlation to the distribution of variations.

CONCLUSION

On observing the 50 specimens of circle of Willis in the present study the following inferences were drawn.

The normal pattern of circle of Willis was observed in 28 cases (56%) cases and the remaining 22 cases (44%) had one or the other variations. 7 cases (31.8%) cases had variations in the anterior circulation and 15 cases (68.2%) had variations in the posterior circulation. Thus, the prevalence of variations is approximately twice in the posterior circulation compared to anterior circulation.

14 cases (63.6%) had variations on the right side compared to 5 variations (22.75%) on the left side. 3 cases (13.65%) had variations in the anterior communicating artery. Thus, the variations are more prevalent on the right side than on the left side. No variations were observed in the middle cerebral artery and basilar artery. Thus, they are the most consistent and least variable vessels in this study. All variations were singular and unilateral. Thus no multiple variations were observed in this study. No aneurysms were observed in any of the specimens. The most common variation observed in the present study is hypoplastic posterior communicating artery (7 cases, 31.8%).

The most variable artery in the present study is posterior communicating artery (11 cases, 50%). The most consistent blood vessel in the present study is middle cerebral artery. No significant deviation has been observed in the study results from what has been reported in the literature. The only exception is the increased incidence of absence of both the anterior and posterior communicating arteries in the present study. This finding is of potential clinical significance to neurologists and neurosurgeons in this geographical location of North Karnataka. A higher incidence of variations in the communicating arteries is likely to manifest as a higher incidence in disorders like migraine, schizophrenia and cerebrovascular disorders due to compromised collateral circulation and poor redistribution of blood. Thus, an exclusive study focusing on the variations of the anterior and posterior communicating arteries with a larger sample size can further establish the higher prevalence of variations of communicating arteries in this geographical area.

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