Research article

Radiological observations of the branches of circle of willis for surgical perception

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ABSTRACT

Introduction and Aim: The Circle of Willis (CoW) is an arterial hexagon in the interpeduncular fossa formed by the basilar and internal carotid arteries. It permits anastomotic circulation between that two-arterial system. Variations in the pattern and the calibre of the arteries that make up the CoW were common. Few noted variations include hypoplasia or aplasia of either one or both posterior or anterior communicating arteries, aplasia, or fenestrations of the anterior communicating artery. Considering the surgical importance of this arterial circle, as it allows equalization of blood flow between the two sides of the brain, this observational study was done to identify the variations in the formation pattern and the gross morphometry of CoW.

Materials and Methods: Thirty radiological images of patients undergoing neurovascular imaging for various reasons in the Department of Radiology and patients were obtained for the study.

Results: Among the 30 studied CT and MR angiographic images, 21 (73.3%) of the circles exhibit the usual pattern of CoW formation, and the remaining 9 (27.7%) showed variations. Among the 30 radiological images, 25 (83.33%) were complete circles, 4 (13.33%) were incomplete in the posterior part and 1 (3.33%) was incomplete in the anterior part of the CoW.

Conclusion: Understanding the typical formation of CoW and its variations is essential in the surgical correction of a few intracranial emergencies like hemorrhage, infarction, aneurysms, and other neurovascular surgeries of the brain.

Keywords: Circle of Willis; Communicating vessels; Hemorrhage; Hypoplastic.

INTRODUCTION

Thomas Willis (1664) gave an illustrated and detailed description of the cerebral arterial network at the base of the brain, along with its functional significance. Hence, it is widely known even to the present as the circle of Willis. It is the seat of functional anastomosis for regional blood flow to most brain areas through its various branches, formed by the terminal segments of vertebral-basilar and internal carotid arterial systems (1,2).

Individual variations in the pattern and calibre of vessels that form the Circle of Willis (CoW) are quite common. The vessels of this circle develop by angiogenesis, i.e., by sprouting from other vessels alongside the development of the neural tube into the brain and spinal cord. The CoW arterial variations occur due to the persistence of an embryonic stage vessel that resulted either due to an absence of an artery that is usually present or abnormal persistence of an embryonic artery (3-6). Although a complete CoW almost always exists in every human, one of its formative arteries is narrowed to a greater extent to reduce it as collateral and make the CoW incomplete functionally. The anterior or posterior cerebral and their communicating arteries may be hypoplastic, absent, double, or even triple (7).

A typical circle of Willis is described as symmetrical and showing no signs of hypoplasia (defined as <1mm for arteries and <0.5mm for the communicating branches) or aplasia, which in turn have been reported to be the most expected anomalies involving the circle. Previous studies have established the prevalence of regular circles to be 34.5% or less (8).

Considering the surgical importance of the CoW formative pattern as it allows equalization of blood flow between the right and left sides of the brain, this observational study was taken up to identify the variations in the pattern of formation of CoW in the radiographic images.

MATERIALS AND METHODS

After ethics committee clearance, 30 radiographic images were taken from the patients undergoing neurovascular imaging for various reasons in the Department of Radiology. The patients having a history of head trauma or any space-occupying lesions were excluded from this study.

CT cerebral angiography technique was performed with 64 rows of Philips Brilliance CT scanner slice thickness of 0.625mm. After injection of 50 ml of IV contrast (Ultravist injection) at the rate of 4 ml/sec using an injector, the scan delay is 4 secs and with 120 KV tube voltage,140mAS, with pitch 1.3. Images obtained were evaluated with the help of the radiologist's guidance.

Magnetic Resonance (MR) Angiography was performed, and the cerebral vasculature's three-dimensional time of flight sequence was evaluated under radiologist supervision. Various parameters were documented.

RESULTS

Among the 30 studied CT and MR angiographic images, 21 (73.3%) of the CoW exhibit the normal pattern of its formation, and the remaining 9 (27.7%) showed variations. If any of the component vessels is absent, the circle of Willis is considered as incomplete or open.

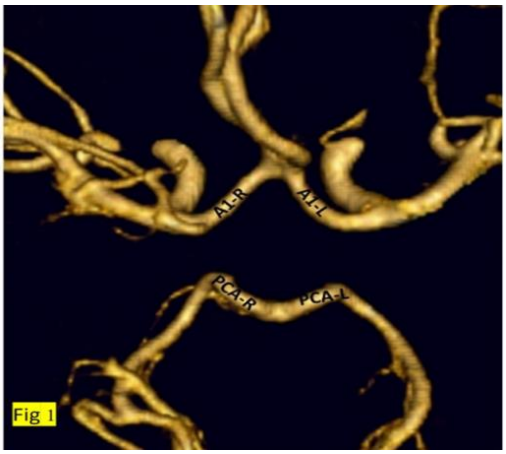

Fig. 1: CT image of incomplete posterior part of CoW

Fig. 2: MR image of incomplete anterior part of CoW

In some cases, the vessels adjacent to the absent vessel anastomose with the neighbouring segment maintain the continuity of the vessels to complete the circle. Among the 30 radiological images, 25 (83.33%) were complete circles, 4 (13.33%) were incomplete in the posterior part (Fig. 1), and it was incomplete in the anterior part of the circle in 1 (3.33%) as represented in Fig. 2.

Anterior communicating artery (AComA) Radiological images

In a usual circle of Willis, the AComA is a short vessel segment that bridges the two anterior cerebral arteries (ACA). It demarcates the ACA's pre-communicating (A1) part from its post-communicating part (A2). The average vessel length among the specimens studied was 4.34mm, and the average diameter was 1.30mm. The AComA was absent in 6 (18.74%) radiographic images. Among these 6 cases of absent AComAs, CoW in one case was open in the anterior part without any communication between the two ACAs and no demarcation between the A1 and A2 segments of ACAs on each side. In the rest, the ACAs united at the site of AComA. In this type, the AComA and the A2 segments of both sides appeared to be fed by the A1 segment of any one side.

Posterior communicating arteries (PComA)

Radiological images: In a usual circle of Willis, the PComAs are given off by the internal carotid arteries (ICA), which later anastomose with the same side posterior cerebral arteries (PCA), which in turn are the branches of the Basilar artery (BA).

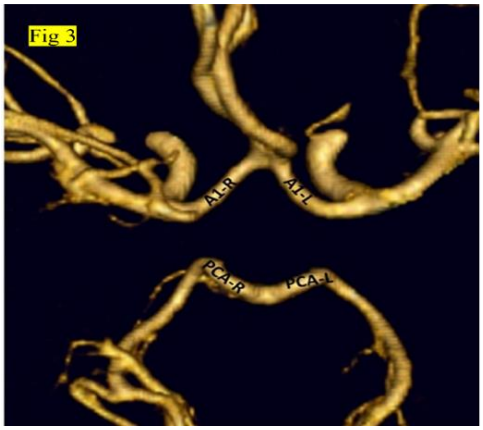

Fig. 3: CT Angiographic image of absent bilateral PComA

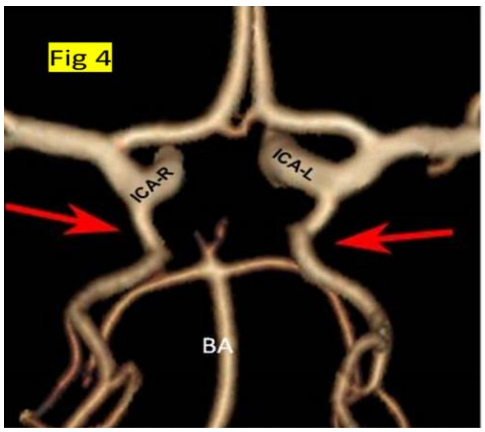

Fig. 4: CT angiographic reconstruction of CoW showing the bilateral fetal type of PComA (red arrows).

This anastomosis divides the PCA into pre-communicating and post-communicating parts, P1 and P2, respectively. Most often, the diameters of these P1-R and P1-L segments are more significant than

those of the PComAs on the same side. Among the 30 radiological images studied, bilateral absence of PComA was seen in 3 cases (Fig. 3). Two fetal types of circles of Willis were seen, one being unilateral and the other bilateral (Fig. 4).

The average lengths of the various vessels forming the circle of Willis are shown in Table 1.

Table 1: Morphometry of the component vessels of CoW

Component vessel	Average length (mm)	(n)
AComA	4.303 ± 1.923	26
PComA-R	14.512 ± 3.723	26
PComA-L	14.324 ± 4.420	29

DISCUSSION

Many studies have shown that CoW shows variations due to the involvement of numerous vessels. It has also been shown that variations exist in the pattern of its formation. The presence of a typical circle of Willis ranges from 4.6% to 72.2% (9). There are many reasons for this wide range of findings. It could be due to disparity in the nomenclature from author to author, different methods of assessing the formation used by different authors, etc., Therefore, we tried to describe the variations in component vessels of CoW in terms of its anterior and posterior circulations.

Bergmann mentioned that the normal CoW is valid only in 34.5% of cases (9). Hartkamp *et al.,* in their radiographic finding, reported that the circle of Willis is regular and complete in 42% of cases (10). Fawcett and Blackford documented 96.1% of the complete CoW (11). Eftekhar *et al.,* reported 31.5% of cases where the circle of Willis was usual (8). Maaly and Ismail reported that the CoW was complete in 46.7% of cases, partially complete in 37.2%, and incomplete in 16.1% (12).

In the present study, among the 30 studied neurovascular images, 73.3% of the circles were found to fit the textbook description of CoW, and the remaining 27.7% showed variations. The imaging studies showed 16.66% variations in the anterior part of the circle, 10% in the posterior part, and 3.33% in both parts of the circle. It concurred that the anterior part anomaly includes variations such as duplicity. In contrast, the posterior part variations due to hypoplasia or the absence of one or more segments. It was found that the posterior circulation, even when anomalous and variant, receives more blood supply when compared to the anterior part. This is also observed among the other workers, Kamath (10,13-16). The present study showed more anomalies in the anterior part of CoW than its counterpart.

Anterior communicating artery

Radiographic images showed that 86.6% of the AComA was present and single. The double or fenestrated vessel was in 3.3%. Also, the present study showed an equal proportion of ACom A with Y-shaped (6.6%) and network type (3.3%). In his experiments, Windle found that the AComA was absent in 3% and doubled in 3% of cases (17). Also, he mentioned absent AComA in 3% and double in 3% (17). Fawcett reported single AComA in 92.1%, nil in 0.14%, and found it to be double in 7.2% (11). In another study by Vare and Bansal, the AComA was absent in 1.14%, double in 10.28%, and the AComA-ACA complex was 'H' shaped in 1.14% (18). Luzsa noted that the artery was absent in 0.3% and the occurrence of a median trunk in 1.2% of the cases (19). Orlandini *et al.,* (14) reported no AComA in 7% of the cases.

Posterior communicating artery [PComA]

Many authors in the past have extensively found variations in the PComA. In his study, Windle reported the absence of the PComA bilaterally in 15% of cases and unilaterally in 11% of cases (17). He also reported the hypoplastic vessel in 3.5% of cases. Likewise, other authors' reports supported this (11, 21-24).

The present radiological study revealed that PComA was absent bilaterally in 3 cases. However, more variations were seen in the cadaveric specimens – PComA was absent bilaterally in 1 case, unilaterally in 1 case, and hypoplastic in 1 case. However, the fetal type of PComA was observed in the radiological study.

Embryonic/fetal configuration of the CoW

The fetal configuration of CoW is considered only when the PComA's diameter should be greater than that of the ipsilateral P1 segment 16, 20). Two (6.67%) such types were observed in out of the 30 radiological images included in the present study. Many authors have already reported the fetal configuration of CoW in the past.

Interestingly, Schomer *et al.,* studied the PComAs of infarcted brains and found that the smaller diameter (<1mm) or absence of PComA is a risk factor for ischemic cerebral infarction in individuals with occluded internal carotid arteries. Few authors found an inverse relation between PComA and P1 segment (13,15). A similar relation was not observed in the present study (25). Variations of the CoW interrupt the circulation between the formative arteries of CoW and produce cerebral vascular disturbances (26, 27).

CONCLUSION

The present study confirmed that the CoW formation is complete in most of the cases but more often associated with the open part in their posterior part and rarely with the open anterior part and embryonic variety. Knowledge of the normal pattern of CoW and its variations is essential in surgical corrections of neurological emergencies like haemorrhage,

infarction, aneurysms, and neurovascular surgeries related to the brain.

CONFLICT OF INTEREST

The authors have no conflicts of interest.

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