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RESEARCH ARTICLE

ANATOMICAL VARIATIONS OF POSTERIOR CEREBRAL AND POSTERIOR COMMUNICATING ARTERY OF CIRCLE OF WILLIS – A CADAVERIC STUDY

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ABSTRACT

Introduction: The Circle of Willis is a vascular network formed at the base of skull in the interpeduncular fossa. Its anterior part is formed by the anterior cerebral artery, from either side. Anterior communicating artery connects the right and left anterior cerebral arteries. Posteriorly, the basilar artery divides into right and left posterior cerebral arteries and each joins to ipsilateral internal carotid artery through a posterior communicating artery. Anterior communicating artery and posterior communicating arteries are important component of circle of Willis, acts as collateral channel to stabilize blood flow. In the present study, anatomical variations in the circle of Willis were noted.

Material and Methods: 75 apparently normal formalin fixed brain specimens were collected from human cadavers. 54 Normal anatomical pattern and 21 variations of circle of Willis were studied. The Circles of Willis arteries were then coloured, photographed, numbered and the abnormalities, if any, were noted.

Result: Twenty one (21) variations were noted. The most common variation observed is in the Posterior communicating arteries, and posterior cerebral artery was found in 21 specimens.

Conclusion: Knowledge on of variations in the formation of Circle of Willis, all surgical interventions should be preceded by angiography. Awareness of these anatomical variations is important in the neurovascular procedures.

INTRODUCTION

The circle of Willis is a polygonal structure of blood vessels present at the base of brain which distributes oxygen-rich arterial blood to the cerebral mass (1). It was described by Thomas Willis (1621 – 1675) in his book Cerebri Anatome in 1664. Fallopius (1523 – 62) gave the first reasonably correct description of basal arterial ramifications except for the posterior communicating artery which he thought to be indirectly connected with the internal carotid artery through a network of small arteries. Casserius (1561 – 1616) corrected this mistake unilaterally (2, 3). Twenty years later, Vesling (1598 – 1649) illustrated a complete posterior communicating artery but failed to demonstrate an unequivocal union of anterior cerebral arteries. Thomas Willis, assisted by Richard Lower and Christopher Wren, acknowledging the previous studies, provided the first complete illustration of cerebral arterial circle with its anastomotic nature (2, 3). The base of the brain is the place where the vertebro-basilar system and internal carotid system of vessels anastomose. The anastomosis of these two systems occurs in the interpeduncular cistern and forms an arterial circle called 'Circle of Willis'. The internal carotid artery terminates by dividing into anterior and middle cerebral arteries. It also gives anterior choroidal, posterior communicating and ophthalmic arteries at the base of the brain. The basilar artery is formed by the union of right and left vertebral arteries at the lower border of the pons. It terminates by dividing into two posterior cerebral arteries at the upper border of the pons. This anastomosis assists to slow down the blood before it reaches the brain and helps in collateral circulation. The pulsations of the arteries also help in drainage of the cerebrospinal fluid in the interpeduncular cistern. Many variations have been reported in arteries forming the circle in their formation, development and size (4). Different abnormalities such as absence or aplasia, split, hypoplastic and accessory vessels had been observed (5-9). The variation in the arterial circle, which is associated with alteration of blood flow to the brain, enhances the problem in the vascular diseases of the brain (10-11). So identification of such variations in a specific population is important in the evaluation of cerebral vascular morbidity for adequate treatment. The objective of this study was to find the variations in the anatomy of the arterial circle of Willis.

MATERIALS AND METHODS

Study was done in the Department of Anatomy Government Medical College, Jagadalpur, Chhattisgarh. The study was started by undertaking the institutional ethical clearance. After it was continued at Gouri Devi Institute of Medical Sciences and Hospital, Rajbandh, Durgapur, West Bengal, India. The Circle of Willis was studied on 75 formalin preserved brains of human cadavers. The cap of the skull was removed with the circumferential incision one centimetre (1 cm) above the supraorbital margin anteriorly and external occipital protuberance posteriorly, using a saw. A hammer was used to separate the skull cap the dura mater was incised from frontal crest and crista galli anteriorly, extending backwards to the internal occipital protuberance, on either side of superior sagittal sinus. The occipital lobes were supported with one hand while the other hand was used to free the brain from the cranial fossae. First, the olfactory nerves were gently cut by elevating frontal lobe from anterior cranial fossa. Next, the optic nerves were cut, followed by cutting both internal carotid arteries, infundibulum and oculomotor nerves. The attached margin of tentorium cerebelli, on both sides, was incised along the posterior clinoid processes, superior borders of petrous part of temporal bone, and the margins of the grooves for transverse sinuses on the occipital bone, using a long and pointed knife. Falx cerebelli was also cut from the margins of the groove for occipital sinus. The cerebellum was gently pushed back. A long, thin knife was then used to incise the rest of the cranial nerves; the medulla oblongata was incised at the level of foramen magnum and the brain was then gently lifted out of the cranium. The specimen obtained was washed with tap water and placed in a labeled container having 10% formalin solution. After fixation, the base of brain in each specimen was cleaned and cerebral arterial Circle of Willis was identified. The arachnoid mater was removed from the arteries and areas around it. The specimens were duly numbered and sorted out according to classification of the morphological variation of different components of Circle of Willis. Variations of all the segments were noted and were photographed. The variations such as hypoplasia, aplasia, duplication, fenestrations, and difference in dimensions with opposite segments were noted. Observations regarding shape, completeness, symmetry, abnormal architecture were noted. Lastly photographs of the abnormal specimens were taken.

RESULTS

In the present study total 75 fixed human brains were studied. Out of total 75 human brains, 54 (72%) brains has been found to Confirm the classic form of 'Circle of Willis', that was, complete, symmetrical, normal calibre and heptagonal in shape. These 55 specimens have, therefore, been considered as 'Normal'. The rest 21 specimens (28%) of human brain were found as 'variations'. 67 out of 75 specimens (89.33%) of human brain were found 'Heptagonal' in Shape and complete; rest 8 specimens (10.6%) were incomplete and not heptagonal in shape. 55 out of 75 specimens (72%) were found 'symmetric'; rest 21 specimens (28%) were found to be 'asymmetric'. Normal and Complete heptagonal form of circle of willis are found without any Gross Variation Was Found in 54 Cases (72%).

1: Twenty One different types of incomplete and complete heptagonal form of circle of willis are found in this present study.

1. Classical type of Circle of Willis was seen in 54 specimens.
2. Five types complete heptagonal and incomplete form of Circle of Willis associated with the variations of P1 of PCA,
3. Nine types complete heptagonal and incomplete form of Circle of Willis associated with the variations of PCoA.

Several types of variations in 'Circle of Willis' were found during the course of study. They are described as follows:

One specimen was found the incomplete form of Circle of Willis with variations of Posterior cerebral arteries. The right posterior cerebral artery was originating from the right internal carotid artery at proximal to its termination. From its origin, the right posterior cerebral artery passed backward over the right optic tract winding around the cerebral peduncle to reach the tentorial cerebral surface. The left posterior cerebral artery originated as a terminal branch of the basilar artery. But the termination of basilar artery was took place somewhere in the middle of the basilar sulcus of the pons, and then turned to the left and backward between the temporal lobe of the cerebrum and pons above the middle cerebellar peduncle to reach the tentorial cerebral surface of cerebrum. Further course and distribution of right and left posterior cerebral arteries were normal (Fig: 1)

One Complete, non heptagonal form of Circle of Willis was found and it showing the following variations with right and left Posterior cerebral arteries, right and left posterior communicating arteries and Internal carotid arteries. The left internal carotid artery was slightly larger compared to the right internal carotid artery. The right posterior communicating artery is hypoplastic and the left posterior communicating artery is hyperplastic almost the size of middle cerebral artery, and anastomosis with the right posterior cerebral arteries. The right posterior cerebral artery is normal then the left posterior cerebral artery. The left posterior cerebral artery is hypoplastic and the P1 segment is longer than p1 segment of right and it anastomosis with the left posterior communicating artery and thereafter, the posterior communicating artery continued as the posterior cerebral artery (Fig : 2).

Two Complete, heptagonal form of Circle of Willis with Variation of P1 segment of right posterior cerebral artery was observed hypoplasia. Hypoplasia of P1 segment of The Right PCA in the two specimens (Fig: 3).

Incomplete form of Circle of Willis was seen and showing an abnormal course and uncommon anomaly in the right Posterior cerebral artery. The right PCA is hypoplastic and it is dividing into three slender branches at the distal portion of P1 segment. One of its branches is joining hyperplastic anterior choroidal artery which is originating from the right Internal Carotid Artery and PCoA are absent on both sides (Fig: 4).

Complete heptagonal, form of Circle of Willis was seen in four specimens and those were showing unilateral hypoplasia of Posterior Communicating Arteries (Fig: 2, 5)

Complete heptagonal, form of Circle of Willis was seen in four specimens and it was showing bilateral hypoplasia of Posterior Communicating Arteries (Fig: 6).

Two Incomplete form of Circle of Willis was seen and it showing unilateral Aplasia of right Posterior Communicating Artery (Fig 7).

Two Incomplete form of Circle of Willis was seen and it showing unilateral Aplasia of left Posterior Communicating Artery.

Incomplete no heptagonal form of Circle of Willis was found in four specimens and those were showing bilateral Aplasia of right and left Posterior Communicating Arteries. (Fig: 1, 4, 9 & 10).

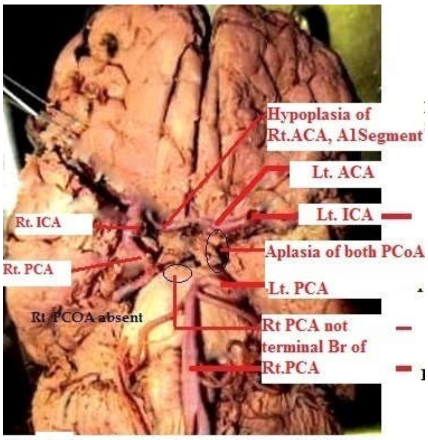

Fig 1: Showing Aplasia of Rt & Lt PCoA, Unusual origin of Rt. Posterior Cerebral Artery from Rt. Internal Carotid Artery.

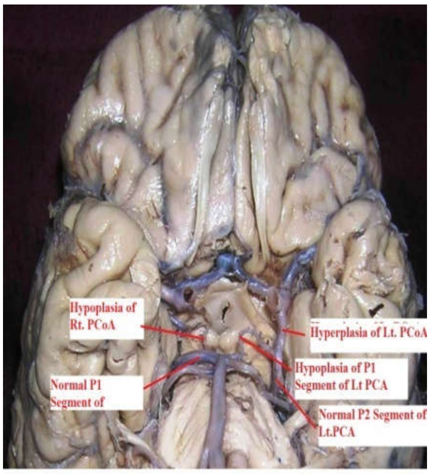

Fig 2: 1. Showing Normal pattern of Rt. Posterior Cerebral Artery and Hypoplastic Rt. Posterior Communicating Arteris
2. Showing Hypoplasia of Lt. Posterior Cerebral Artery & Hyperplastic Anterior Communicating Arteris

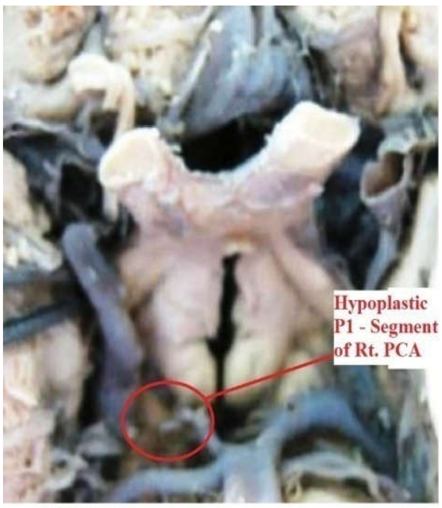

Fig 3: showing Hypoplasia of the Posterior Cerebral Artery (right P1 segment)

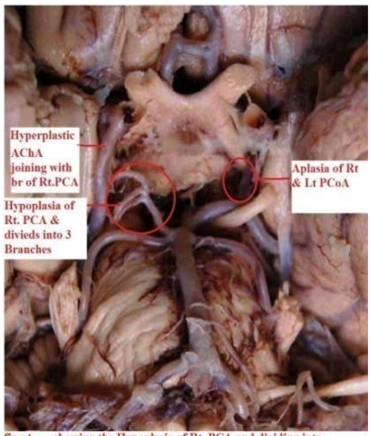

fig : 4 showing the Hypoplasia of Rt. PCA and dividing into branches, One of the Branch is joining with Hyperplastic Anterior Choroidal Artery. Bilateral Aplasia of PCoA

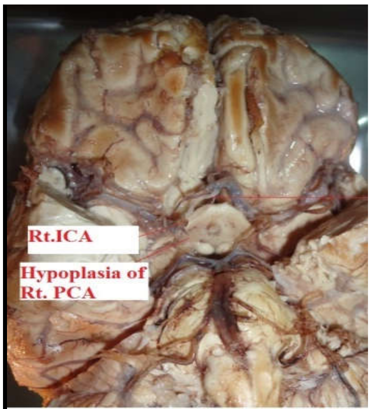

Fig 5 : Showing unilateral Hypoplasia of Rt.Posterior Communicating Arteries

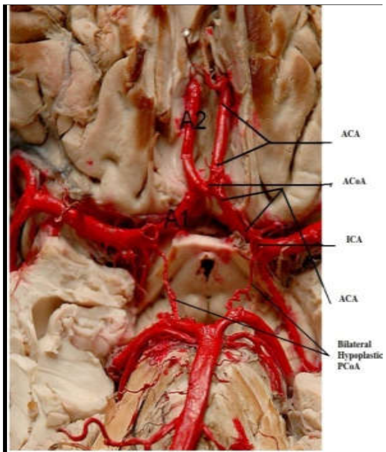

Fig 19 Bilateral Hypoplasia of PCoA

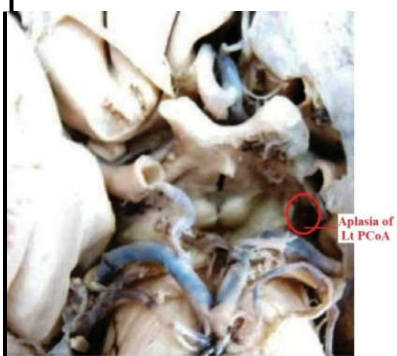

Fig 7 : Aplasia of Left Posterior Communicating Artery

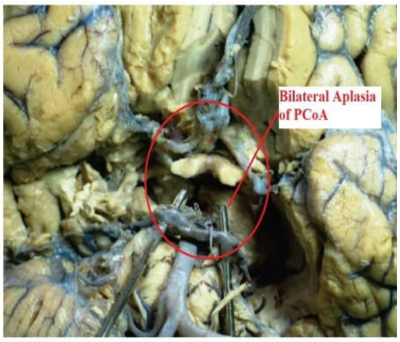

Fig 8 : Showing bilateral Aplasia of Posterior Communicating Arteries

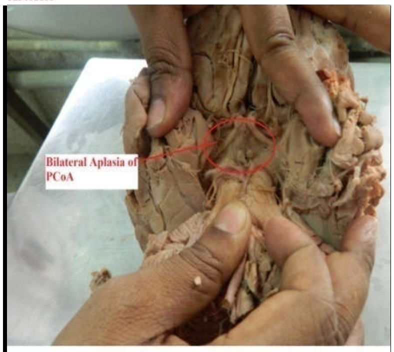

Fig 9 : Showing Bilateral Aplasia of Posterior communicating Arteries

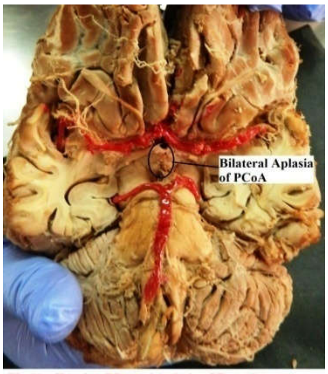

Fig 10 : Showing Bilateral Aplasia of Posterior Communicating Arteries

Table 1 Anatomical variations

Variation type	Number of Variations	Percentage %
Complete and normal CW	54	72
CW gross variations	32	42.66
PCA - P1 Segment	6	8
PCoA	16	21.33
AChA	1	1.3

Table 2 Symmetry of different components of Circle of Willis

Segment of CW	Symmetrical	Asymmetrical
PCoA	66 (88 %)	9 (12 %)
PCA – P1	71 (94 %)	4 (5.33%)

Table 3 Percentages of different variations of Circle of Willis.

Components	Variations	Right	Left	Number of	%	Total	Total %
PCA	Hypoplasia	4	--	4	4	6	8 %
	hyperplasia	--	1	1	1.3		
	Arise from Rt. ICA	1	--	1	1.3		
PCoA	Hypoplasia	7	5	12	16		
	Hyperplasia	--	1	1	1.3	25	33.33%
	Aplasia	6	6	12	16		
AChA	Hyperplasia	1	--	1	1.3	1	1.3 %

DISCUSSION

Blood supply to the brain is mainly from the circulus arteriosus and Thomas Willis was pioneer in describing Circle of Willis in 1962 [4]. Since then, many authors have reported number of anatomical variations in the formation of Circle of Willis [12, 13]. Variations of the origin and distribution of the arteries at the base of the brain are common. All these variations are either due to the disappearance of the vessels that normally persist or the persistence of the vessels that normally should disappear or formation of new vessels due to hemodynamic factors. In most of the arterial variations, the brain function may not be affected due to the collateral circulation and compensation from the arteries of the other side [14]. A thorough knowledge of the variations in cerebral arterial circle has grown in importance with the increasing number of procedures like aortic arch surgery, microsurgical clipping of anterior communicating artery aneurysms; its variations are common and the textbook picture of symmetrical, large, approximately equal sized vessels were present only in 30% subjects.(7,15-17). The prevalence of the 'typical or classic circle', the "normal" textbook polygon ranges from 4.6% to 72.2% [18]. A possible reason for the wide range may be the diversity in nomenclature and the criteria used to define hypoplastic vessels. There is little unanimity in nomenclature and quantitative measurement of the diameters of all the component vessels of 'circle', which has not been measured in several studies and has relied upon rough estimations of the vessel diameter in determining the anomalies of the CW rather than actual measurements. Vessels have been described as 'thread-like', 'string-like', 'minute', and 'very small' without regards to measured diameter.

In the present study, typical or classic configuration was found only in 72% and variations found in the rest 28% of the brains. These observations appear to be more or less in according with those of Windle (1888) [18], Fawcett (1905) [19] who observed normal pattern in 72.8% to 82.5% cases and variant pattern in 18% to 27.2%. But the present observation are at great variance with those of Alper's *et al* (1959) [5], Baptista (1963)[20], who recorded typical or classic pattern in 30% to 90% and variant in 10% to 70% cases. As mentioned earlier, in our present study most of the variations are seen in posterior communicating artery (33.33 %, table 3), followed by Posterior cerebral artery (8 %) in this present study.

Abnormalities in the origin of posterior cerebral arteries are very rare. In this present study the variations in posterior cerebral artery seen is 8%. An uncommon anomaly was found in this study in a brain specimen the right P1 segment (hypoplasia) of Rt posterior cerebral artery (PCA) is very thin compared to the contralateral side and is dividing into slender branches at distal end of P1 segment. One of its branches is joining the hyperplastic anterior choroidal artery. The normal AChA has potential anastomoses with its neighbouring arteries, especially with the PCoA and PCA (22). Hyperplasia of the AChA seems to represent a situation in which one of those anastomoses remains and enlarges as a main pathway of the artery, while a segment of the PCA just proximal to the anastomosis eventually attenuates (23). Although a study conducted by Macchi *et al*. reports that the possibility of origin of posterior cerebral artery from internal carotid artery is about 13%, there are hardly any other reports of origin of posterior cerebral artery from internal carotid artery.[24]. They have also observed about 2% of cases, where absence of a posterior communicating artery was associated with the origin of a posterior cerebral artery from the internal carotid artery as reported in the present study.[24]. There are some cases of hypoplasticity in posterior cerebral artery; however, this is reported to be less than that in the posterior communicating artery.[25]. According to Voljevica *et al*., among the variations that damage the posterior segment of circle of Willis, the unilateral posterior cerebral artery is the most common, followed by unilateral aplasia or hypoplasia of the posterior communicating artery.[26]. In a report by Kapoor *et al*., multiplication of posterior cerebral artery was observed in 2.4% cases while it was hypoplastic in 10.6% brains; (21).

In this present study the most common variation is seen in the posterior communicating artery (33.33%), most common type & most frequent variation found in the present study Aplasia (12%) followed by is the hypoplasia of PCoA (12%). These results were in accordance with the previous reports.(5,6,21). Some reports state that the posterior communicating artery is the most common site of abnormalities in the posterior part of the circle.[25]. In most cases, it is either absent or hypoplastic.[25]. A study conducted on cadavers revealed 51% cases of bilateral hypoplastic posterior communicating artery and 13% cases of unilateral hypoplastic posterior communicating artery. However, in the present study, there was complete absence of bilateral posterior communicating artery, and because of that, the posterior segment of circle of Willis was not formed. Such bilateral absence of posterior communicating artery is considered to be one of the rare variations and is reported to be about 5.3%.

Anomalies in the formation of circle of Willis are equally important for clinicians and surgeons as it is for anatomists. The neurosurgical importance of these variations lies in the exposure of this part of the brain for different purposes. Knowledge of vascular variations will increase the success rate of the surgical procedure.[27] These variations should also be taken into account during the skull base and carotid surgeries, and cerebral angiography. In addition, it has been reported that the incomplete circle of Willis predisposes about one-sixth of individuals to cerebral ischemia during the transient closure of carotid artery, but the risk is more than three times in case of contralateral internal carotid artery occlusion.[25] According to Tanaka *et al*., variations in the circle of Willis correlate significantly with relative contributions by the flow rates of the bilateral internal carotid and basilar arteries, which might significantly contribute to the clinical importance of the variations.[29] According to Alastruey *et al*., in normal subjects, the system does not require collateral pathways through communicating arteries to adequately perfuse the brain. The communicating arteries become important in cases of missing or occluded vessels.[28] It has been reported that the beginning, course, and result of the cerebral-vascular diseases depend hugely on the possibility of establishing collateral blood circulation, especially at the level of circle of Willis. The circle of Willis, through its communicating segments, provides an alternative route for the blood to reach parts of the brain which, due to insufficiency, do not receive enough quantity of blood.[26] However, in cases such as the one reported here, due to the absence of communicating arteries, the alternative routes may not be available.

CONCLUSION

In the present study complete CW was seen in 72%. Gross variations were present in 40%. Maximum variations were present in the PCoA 33.33% followed by the PCA in 8 %, respectively. As it confirms high percentage of variations in the formation of Circle of Willis, all surgical interventions should be preceded by angiography, Awareness of these anatomical variations is important in the neurovascular procedures.

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