

Original Research Article

Anatomical variations of circle of Willis - a cadaveric study

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ABSTRACT

Background: The circle of Willis (CW) 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 join 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.

Methods: 75 apparently normal formalin fixed brain specimens were collected from human cadavers. 55 Normal anatomical pattern and 20 variations of circle of Willis were studied. The Circles of Willis arteries were then colored, photographed, numbered and the abnormalities, if any, were noted.

Results: Twenty variations were noted. The most common variation observed is in the anterior communicating artery followed by some other variations like the Posterior communicating arteries, Anterior cerebral artery and posterior cerebral artery (PCA) was found in 20 specimens.

Conclusions: 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.

Keywords: ACA, ACoA, CW, PCA, PCoA, Variations of circle of Willis

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.

METHODS

This study was done in the Department of Anatomy Government Medical College, Jagadapur, Chhattisgarh, India. 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 skull, was removed with the circumferential incision one centimetre (1 cm) above the supraorbital margin anteriorly and external occipital protuberance posteriorly, by 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, 55 (73.33%) 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 20 specimens (26.66) 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 (89.33%) were found 'symmetric'; rest 20 specimens (22.6%) were found to be 'asymmetric'. Normal and Complete heptagonal form of circle of willis are found without any Gross Variation Was Found in 55 Cases (73.33%).

Twenty different types of incomplete and complete heptagonal form of circle of Willis are found in this present study.

- Classical type of Circle of Willis was seen in 55 specimens.
- 7 types of complete heptagonal and incomplete form of Circle of Willis associated with the variations of A1 segment of Hypoplastic and aplastic anterior cerebral arteries (ACA), along with this other variation associated either with duplication of anterior communicating artery (ACoA), PCA, or aplasia of posterior communicating arteries (PCoA) (9.3%).
- Ten types of complete heptagonal and incomplete form of Circle of Willis associated with the variations of ACoA, along with this other variation associated either with ACA, PCA, or PCoA.
- Four types complete heptagonal and incomplete form of Circle of Willis associated with the variations of P1 of PCA, along with this other variation associated either with ACA, ACoA, or PCoA.
- Nine types complete heptagonal and incomplete form of Circle of Willis associated with the variations of PCoA, along with this other variation associated either with ACA, ACoA, or PCA.

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

Two Variations are found as Complete, heptagonal form of Circle of Willis with hypoplasia of A1 segment or pre-communicating segment of right anterior cerebral artery,

and arising of an accessory Anterior cerebral artery for A2 segment (Figure 1 and 2).

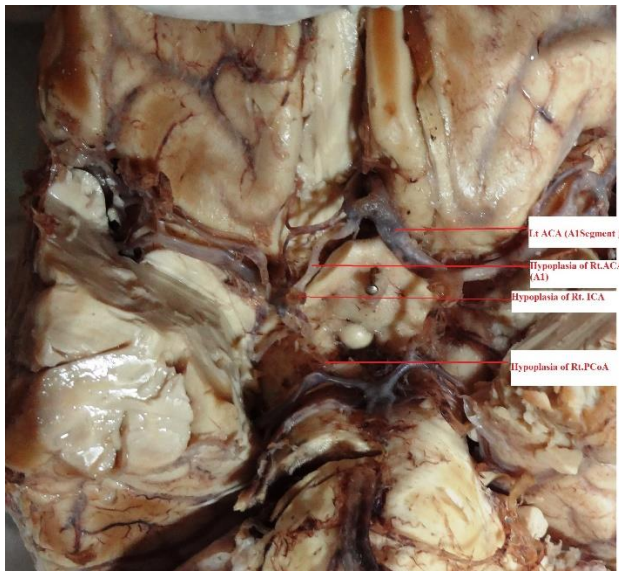


Figure 1: Unilateral hypoplasia on right side of ACA, ICA and PCA.

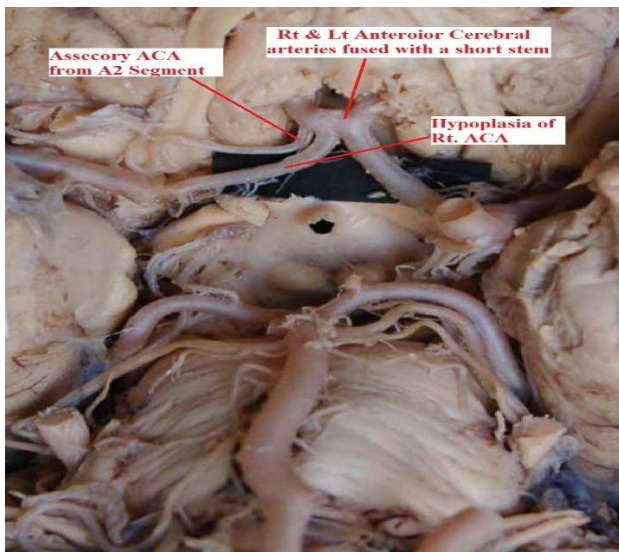


Figure 2: Hypoplasia of A1 segment of right anterior cerebral artery and arising of an accessory anterior cerebral artery, Aplasia of ACoA or Right and Left anterior cerebral artery fused by a short stem.

Three Variations was found as incomplete form Circle of Willis with Hypoplasia of A1 segment of right anterior cerebral artery or pre-communicating segment of left anterior cerebral artery. And also, found bilateral aplasia of PCoA in the three specimens (Figure 3 and 9).

One Variation is found as incomplete form of Circle of Willis with absence or aplasia of left A1 segment or pre-communicating segment of left anterior cerebral artery. (Figure 5). One Variation was found as Complete, heptagonal form of Circle of Willis with Plexiform

pattern of A1 segment or pre-communicating segment of right anterior cerebral artery. The anterior cerebral artery was very small in size (about 2 mm) and it further divided into a few small branches which formed a plexus near the anterior perforated substance. This plexus continued medially above the optic nerve and reunited continued to form a single artery. Further course and distribution of right A2 segment of Anterior Cerebral artery was normal (Figure 6).

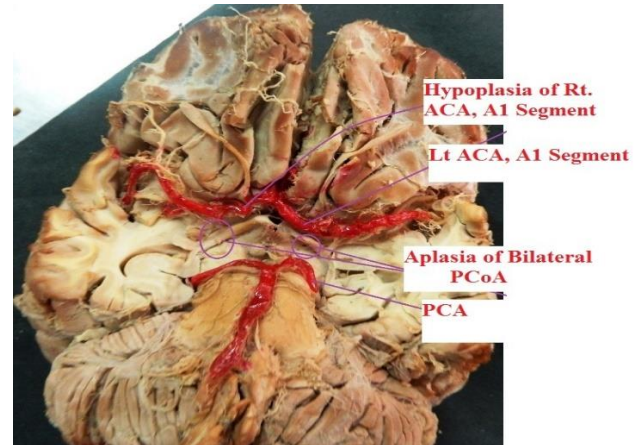


Figure 3: Hypoplasia of A1 segment of Rt. ACA and aplasia of both PCoA.

Complete, heptagonal form of Circle of Willis with duplication of the anterior communicating artery (one proximal and one distal) was seen in four specimens. The diameter all of them were normal. The courses of both ACoA were horizontal in one specimen. In second specimen the course of ACoA Proximal branch was horizontal and distal was oblique in course. In third specimen course of both ACoA, Proximal branch was oblique and distal branch was Horizontal. And in fourth specimen course of both proximal and distal were horizontal, proximal branch was found hypoplastic (Figure 7,10).

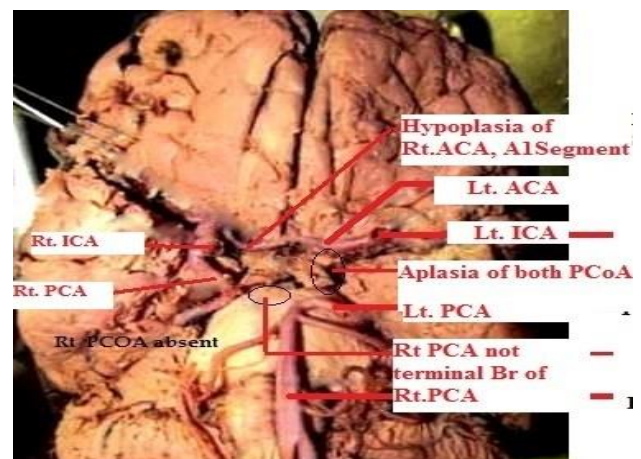


Figure 4: Aplasia of Rt. PCoA, hypoplasia of Rt. ACA, unusual formation of Right PCA and Right ICA.

Two Variations were found as Complete, heptagonal form of Circle of Willis with absence or aplasia of anterior communicating artery, both the right and left anterior cerebral artery were fused (Figure 2 and 6). Complete, heptagonal form of Circle of Willis with Triplication of anterior communicating artery was found in one specimen. Distal two branches were parallel to each other, but the third proximal was obliquely placed. All of them were hypoplastic. The diameter of the last artery was least among three (Figure 8). Incomplete form of Circle of Willis with interconnecting network was present in between the right and left anterior cerebral arteries. The ACoA was showing a Plexiform pattern (Figure 9).

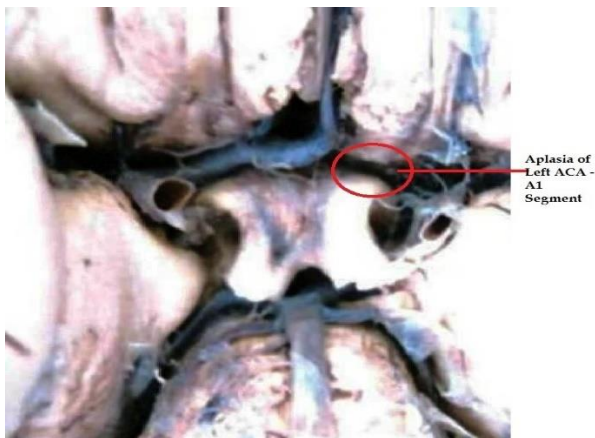


Figure 5: Aplasia of left anterior cerebral artery A1 segment.

When the diameter of anterior communicating artery is less than 1mm, it was considered as hypoplastic. Hypoplastic anterior communicating artery was found in two specimens (Figure 10).

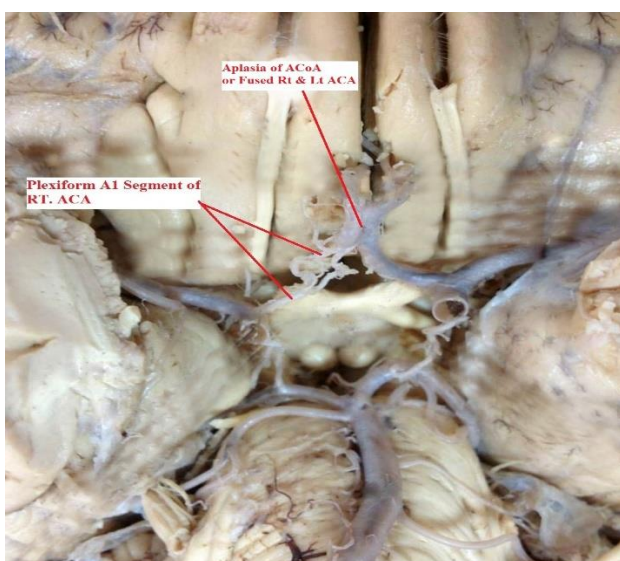


Figure 6: Plexiform pattern of right anterior cerebral artery A1 segment and fusion of Right and Left anterior cerebral artery.

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 (Figure 4).

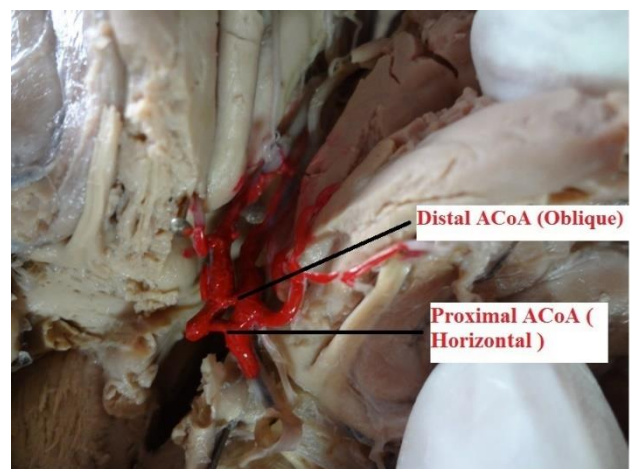


Figure 7: Duplication of anterior communicating artery.

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 (Figure 10). One 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. 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 (Figure 11).



Figure 8: Triplication of anterior communicating artery.

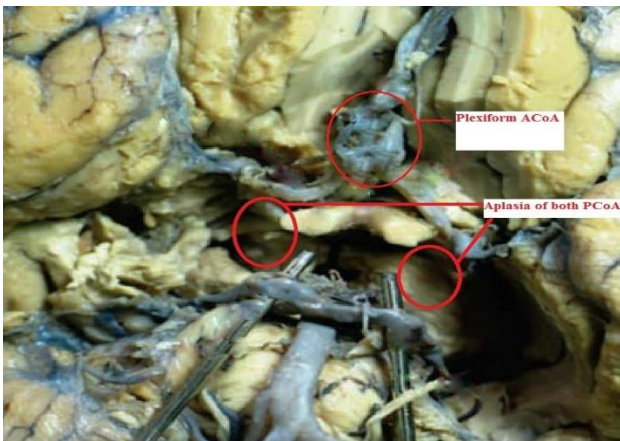


Figure 9: Plexiform of ACoA and aplasia PCoA.

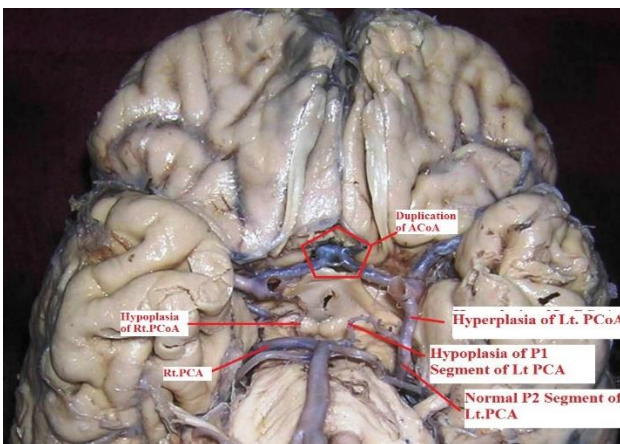


Figure 10: Hyperplasia of posterior communicating artery, hypoplasia of posterior cerebral artery P1 segment and P2 segment of left PCA continuing as normal hypoplasia of right PCoA.

Complete heptagonal, form of Circle of Willis was seen in two specimens and those were showing unilateral hypoplasia of posterior communicating arteries (Figure 1,10). Complete heptagonal, form of circle of Willis was seen in one specimens and it was showing bilateral hypoplasia of posterior communicating arteries (Figure 12).

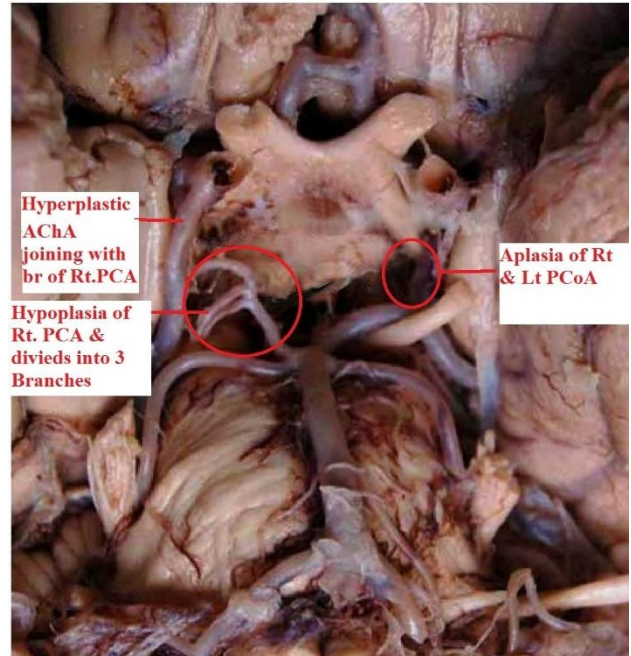


Figure 11: Hypoplasia of right PCA and dividing into branches, one of the branch is joining with hyperplasia anterior choroidal artery, bilateral aplasia of PCoA.

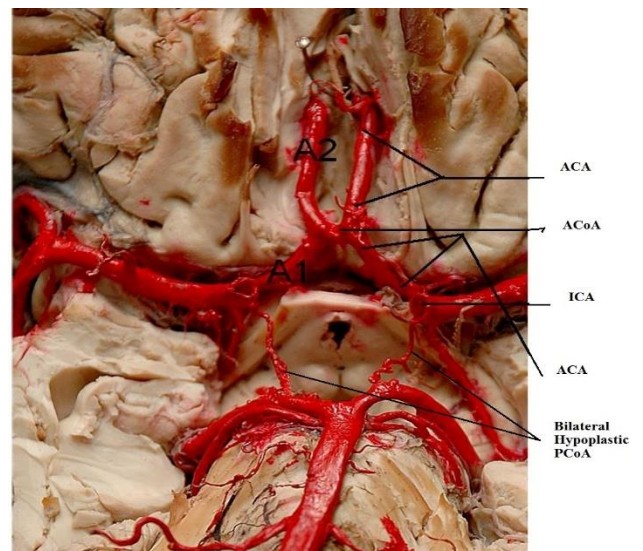


Figure 12: Bilateral hypoplasia of PCoA.

Complete heptagonal, form of Circle of Willis was seen in one specimen and it was showing unilateral hyperplasia of left Posterior Communicating Arteries (Figure 10).

One Incomplete form of circle of Willis was seen and it showing unilateral aplasia of right posterior communicating artery. Incomplete no heptagonal form of Circle of Willis was found in five specimens and those were showing bilateral Aplasia of right and left Posterior Communicating Arteries. (Figure 3,4, 9 and 11).

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}

Table 1: Anatomical variations.

Variation type	Number of variations	Percentage
Complete and normal CW	55	73.33
CW gross variations	30	40
Incomplete CW	8	10.66
ACA - A1 Segment	8	10.66
ACoA	10	13.33
PCA - P1 Segment	4	5.33
PCoA	16	21.33

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 73.33% and variations found in the rest

26.66% of the brains. These observations appear to be more or less in according with those of Windle, Fawcett who observed normal pattern in 72.8% to 82.5% cases and variant pattern in 18% to 27.2%.^{18,19} But the present observation are at great variance with those of Alper's et al, Baptista, who recorded typical or classic pattern in 30% to 90% and variant in 10% to 70% cases.^{5,20} As mentioned earlier, in our present study most of the variations are seen in anterior communicating artery (13.3%), Followed by posterior communicating artery (12%, Table 2), followed by anterior cerebral artery (9.3%) and variations are found in Posterior cerebral artery (5.3 %) in this present study.

Table 2: Symmetry of different components of circle of Willis.

Segment of CW	Symmetrical	Asymmetrical
ACoA	65 (86 %)	10 (13.33%)
ACA-A1	68 (90 %)	7 (9.33 %)
PCoA	66 (88 %)	9 (12 %)
PCA- P1	71 (94 %)	4 (5.33%)

In the present study, the anterior cerebral artery, one of the components of CW has been found to exhibit abnormalities were Hypoplasia on right side is 8%, Aplasia is 1.3% Plexiform pattern is 1.3% by the way of fusion between the arteries of one side with that of the contralateral side, forming fused ACA. 2.6% of such specimens were found. Fusion of the anterior cerebral artery may cause absence of ACOM artery. Absence of ACOM is also possible without fusion of anterior cerebral artery. The ACA has anatomises between them in 2.6% with a short fused A2 trunk and one among the ACA is found to be predominant in the A2 segment. A fused short A2 trunk is more commonly found.²¹ In the A2 segment of the ACA, one ACA is found to be predominant and provides blood supply to both hemispheres in its distal aspect of the cerebral hemispheres.²²

The third ACA or an accessory ACA generation in A2 segment in the study is found in one brain specimens (1.3%) and is found to be originating from the ACoA. This represents our most common finding in the anterior circulation; with 3 cases of "extra ACA", they were all originated directly from the ACoA.²¹ The present observations largely corroborate with those of Windle and Alpers et al who recorded 3% and 2% cases of absence of the ACOM due to fusion of the two anterior cerebral arteries respectively.^{4,18} The present observations fail to demonstrate the complete absence of ACOM without fusion of anterior cerebral artery and so unable to compare the finding with those of Fawcett et al who found complete absence of anterior communicating artery in 0.14% cases.¹⁹ Another form of variation was found, that is, right sided hypoplastic anterior cerebral artery 8%. The diameter below which the segment of ACA that is part of CW could be called hypoplastic has not been well defined, but Perlmutter and Rhoton used 1.5 mm as

the cut off value.²³ They found 10% of the brains to have less than 1.5 mm in diameter in the aforesaid segment. Alpers et al found string like components of one of the vessels of the CW in 28% cases, with that part of ACA being the predominant site.⁵ Riggs and Rupp observed hypoplasia of that part of ACA in 7% cases. Plexiform anterior cerebral artery is a very rare occurrence.⁶ The Plexiform nature of the anterior cerebral artery observed in the present study may be due to the incomplete fusion of the primitive plexiform anterior cerebral artery to form a single vessel.²⁶ This specimen was unique, having a hypoplastic, plexiform initial segment of the right anterior cerebral artery. Since the distal part of the anterior cerebral artery was large and had a fusion with the left anterior cerebral artery, this variation might not cause any functional disturbances. But it might cause serious infarct of both hemispheres in case of thrombosis or rupture of the initial segment of the left anterior cerebral artery because of the poor collateral circulation provided by the artery of the right side.^{20,24} In present literature survey, we could not find a report on occurrence of such a variation. No other form of abnormalities has been found in ACA.

In the present study, the most common variation is seen in the (ACoA) anterior communicating artery (13.3%), most common type of variation is double or duplication of artery. Other variations were hypoplasia, fused artery, Triplication and Plexiform type. Duplication of anterior communicating artery was the most common variation,

which was seen in 5.3% of subjects. Tripling of anterior cerebral artery was least common variation which was seen only in 1.3% of subjects. Same extent of a similar variation was also noted by Kanchan Kapoor, PN Jain and Vare and Bansal.²⁷⁻²⁹ The absence of anterior communicating artery was observed in 2.6% of subjects. Fawcett and Blachford, Blackburn, Von Mitter wallner, Kanchan Kapoor, PN Jain and Vare and Bansal found same variation, but less frequently, to range from 0.14% to 1.8%, as compared to that in the present study.^{19,27-31} Fusion of anterior communicating arteries were seen in 2 cases, the two anterior cerebral arteries were not joined by anterior communicating artery, but they came in close contact with each other, with a fistula formation in between them. This finding agreed with those of other workers. The incidence of this variation was similar to the observation made by Windle, Stopford.^{18,30} The old author using the term fistula is not convincing recent study done by Kanchan Kapoor included this variation of fused anterior communicating artery as the absence of artery.²⁷ Berk and Stopford had reported duplication of anterior communicating artery in 9% and 7.9% cases respectively.^{32,33} Vare and Bansal mentioned in their study, that in duplication or triplication of the vessel, the posterior most artery had a smaller size, which was similar to that which was seen in the present study.²⁹ Various forms of duplications of anterior communicating artery and the incidence of this variation in present study were similar to the findings of study done by Kanchan Kapoor.²⁷

Table 3: Percentages of different variations of circle of Willis.

Components	Variations	Right	Left	Number of	%	Total	Total %
	Hypoplasia	5	--	5	8		
ACA – A1	Aplasia	--	1	1	1.3	7	9.3%
Segment	Plexiform	--	1	--	1.3		
	Accessory	1	--	1	1.3		
	Duplication	--	--	4	5.3		
ACoA	Triplicaton	--	--	1	1.3		
	Hypoplasia	--	--	3	4	10	13.33%
	Fused	--	--	2	2.6		
	Plexiform	--	--	1	1.33		
	Hypoplasia	2	--	2	2.6	4	5.3%
PCA	hyperplasia	--	1	1	1.3		
	Aplasia	1	--	0	0		
	Hypoplasia	3	1	3	4		
PCoA	Hyperplasia	--	1	1	1.3	16	21.33%
	Aplasia	5	6	9	12		
AChA	Hyperplasia	1	--	1	1.3	1	1.3 %

In the present study, 1.3% cases had persistence of plexiform pattern of anterior communicating artery, between the two anterior cerebral arteries. A similar variation with same frequency was observed by von Mitter wallner.³¹ Other studies found this variation to be

less frequent. The anterior communicating artery appears in human embryo of size 18 mm, as a reticulated anastomosis between the two anterior cerebral arteries.²⁰ The preservation of plexus or network of vessels between the two anterior cerebral arteries exists in few adult

brains, as was observed in present study. Very few variations were seen during vessels. Two anterior communicating arteries seen in the present study had an oblique course. In two cases, the anterior communicating artery was seen in the median fissure. This variation during anterior communicating artery was associated with long and straight course of the anterior cerebral artery. Similar variations were mentioned by Vare and Bansal, Kapoor K in their study.^{27,29}

Abnormalities in the origin of posterior cerebral arteries are very rare. In this present study, the variations in posterior cerebral artery seen is 5.33%. 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 neighboring arteries, especially with the PCoA and PCA.³⁴ 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.³⁵ 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.³⁷ 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.³⁷ There are some cases of hypoplasticity in posterior cerebral artery; however, this is reported to be less than that in the posterior communicating artery.³⁶ 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.³⁵ 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.²⁷

In this present study, the most common variation is seen in the posterior communicating artery (21.33%), most common type and most frequent variation found in the present study Aplasia 12% followed by the is hypoplasia of PCoA (5.33%). These results were in accordance with the previous reports.^{5,6,27,33} Some reports state that the posterior communicating artery is the most common site of abnormalities in the posterior part of the circle.³⁶ In most cases, it is either absent or hypoplastic.³⁶

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 one of the rare variations and is reported to be about 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.³⁹ These variations should also be considered 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.³⁶

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.⁴⁰ 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.⁴¹

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.³⁸ 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 73.33%. Gross variations were present in 40%. Maximum variations were present in the PCoA 22% followed by the ACoA in 13.33%, 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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