International Journal of Anatomy and Research,
Int J Anat Res 2017, Vol 5(2.3):3882-90. ISSN 2321-4287
DOI: https://dx.doi.org/10.16965/ijar.2017.179

Original Research Article

# ANATOMICAL VARIATIONS OF ANTERIOR CEREBRAL ARTERY AND ANTERIOR COMMUNICATING ARTERY: 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.

**Materials and 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 coloured, photographed, numbered and the abnormalities, if any, were noted.

**Result:** 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 was found in 20 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.

**KEY WORDS:** Circle of Willis (CW), Variations of Circle of Willis, Hypoplastic and Aplastic Anterior Cerebral Arteries (ACA), Duplication of Anterior Communicating artery (ACoA) Fused ACoA, and triplication of Anterior Communicating Artery .

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| Quick Response code | Web site: International Journal of Anatomy and Research ISSN 2321-4287 www.ijmhr.org/ijar.htm | |
|---|---|---|
| DOI: 10.16965/ijar.2017.179 | Received: 09 Mar 2017<br>Peer Review: 10 Mar 2017<br>Revised: None | Accepted: 15 Apr 2017<br>Published (O): 30 Jun 2017<br>Published (P): 30 Jun 2017 |

## 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 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 labelled 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 54 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. 54 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%).

Twenty 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) Eight types of complete heptagonal and incomplete form of Circle of Willis associated with the variations of A1 segment of ACA (10.6%).

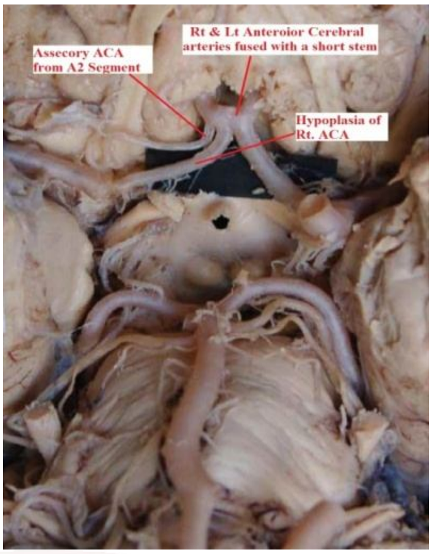
(3) Thirteen types of complete heptagonal and incomplete form of Circle of Willis associated with the variations of ACoA, (17.66%)

Several types of variations in 'Circle of Willis' were found during the course of 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. (Fig. 1, 2).

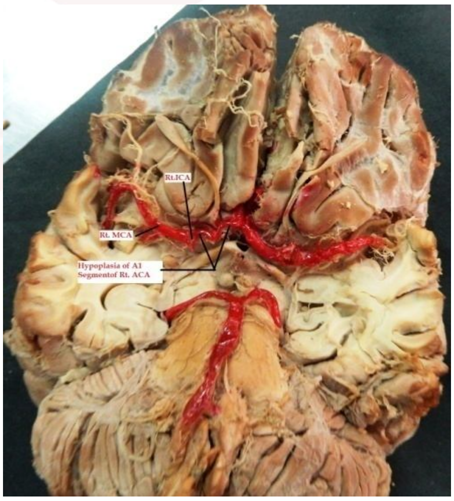
**Fig. 1:** Showing Unilateral hypoplasia on right side MCA, ICA and PCA.

**Fig. 2:** Showing hypoplasia of A1 segment of Right Anterior Cerebral Artery and arising of an accessory Anterior Cerebral Artery.




Three Variations is 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.(Fig. 3, 4, 5)

**Fig. 3:** Showing hypoplasia of A1 segment of Right Anterior Cerebral Artery.



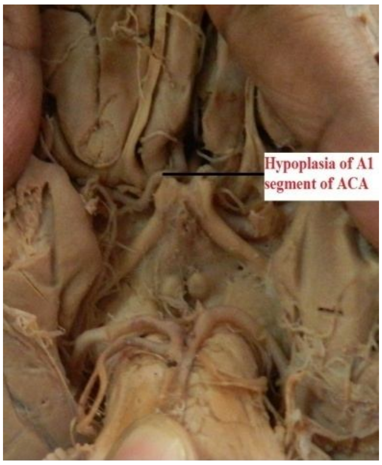
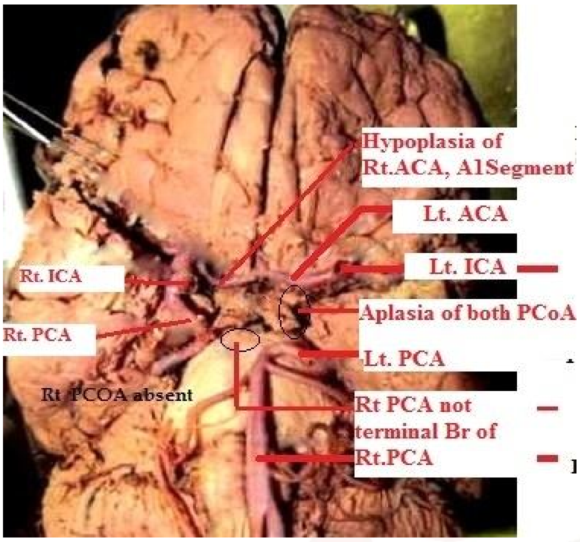


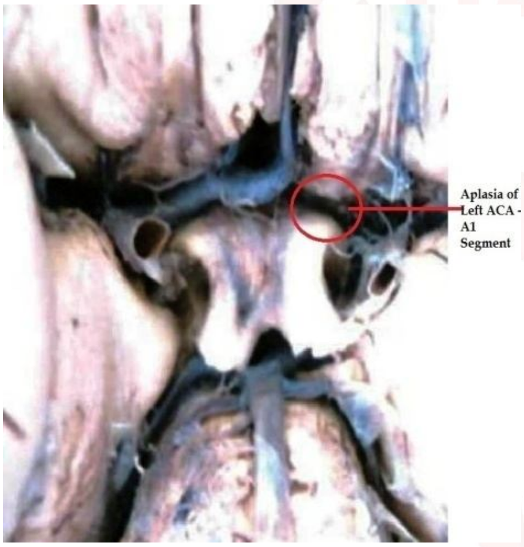

**Fig. 4:** Showing hypoplasia of A1 segment of Right Anterior Cerebral Artery.

**Fig. 5:** Showing Aplasia of A1 Right Posterior Communicating artery and Right Anterior Coronary artery, Unusual formation of Right posterior communicating artery from right internal carotid artery.



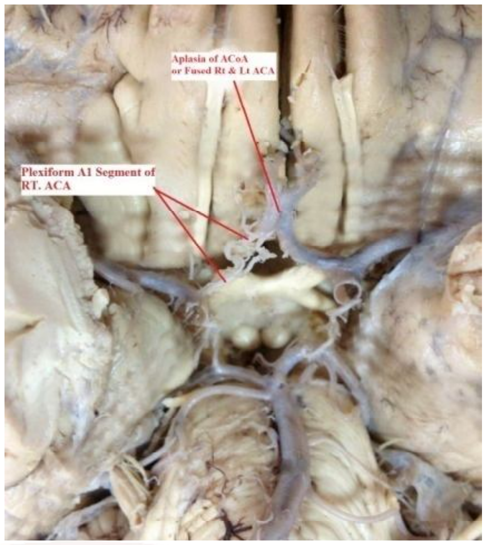

One Variation is found as incomplete form of Circle of Willis with absence or aplasia of left A1 segment or pre-communicating segment of left anterior cerebral artery. (Fig. 6)

**Fig. 6:** Aplasia of Left Anterior Cerebral Artery A1 segment.




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 (Fig. 7)

**Fig. 7:** Showing plexiform pattern of Right Anterior Cerebral artery A1 Segment and fusion of Right and left Anterior Cerebral Artery.




Complete, heptagonal form of Circle of Willis with duplication of the anterior communicating artery (one proximal and one distal) was seen in five 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. (Fig. 8,9,10,11)

**Fig. 8:** Duplication of Anterior Communicating Artery.

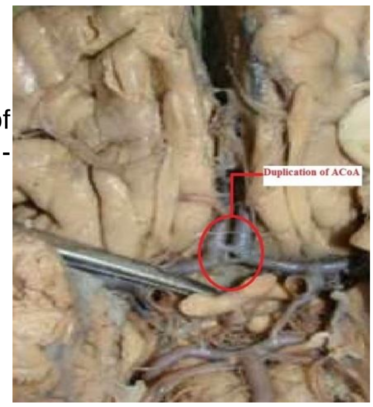



**Fig. 9:** Duplication of Anterior Communicating Artery.

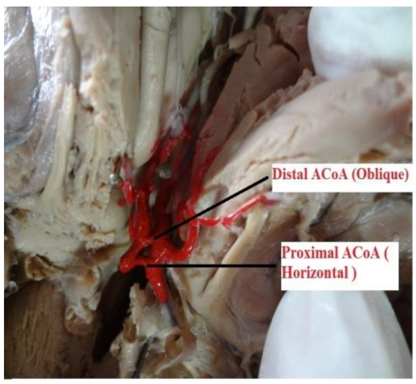


**Fig. 10:** Duplication of Anterior Communicating Artery and hypoplasia of Right anterior communicating artery (A1, A2 Segment).

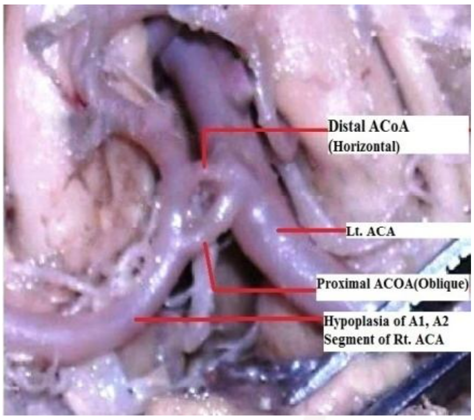
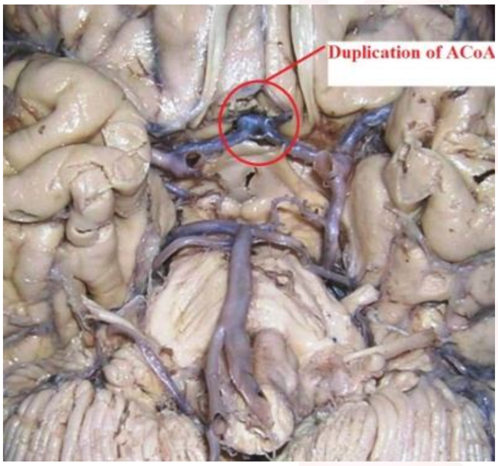


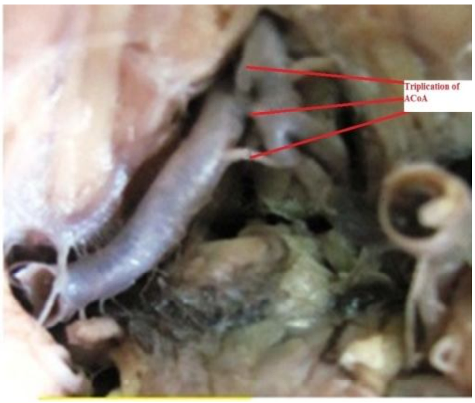

**Fig. 11:** Duplication of Anterior Communicating Artery.




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 (Fig 2 & 7).

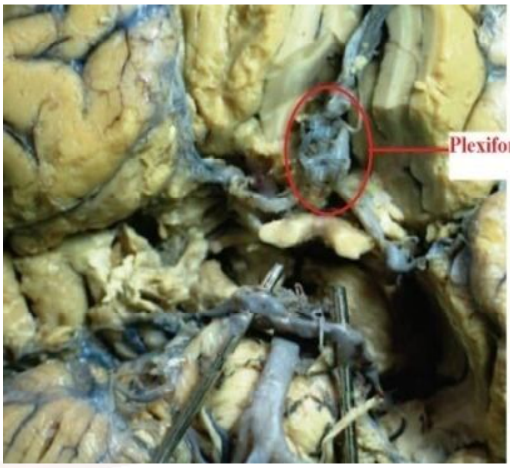
Complete, heptagonal form of Circle of Willis with Triplication of anterior communicating artery was found in one specimen. Distal two branches were parallel to each other, but the third proximal was obliquely placed. All of them were hypoplastic. The diameter of the last artery was least among three (Fig 12).

**Fig. 12:** Triplication of Anterior Communicating Artery.




Incomplete form of Circle of Willis with inter-connecting network was present in between the right and left anterior cerebral arteries. The ACoA was showing a Plexiform pattern (Fig. 13).

**Fig. 13:** ACoA was showing a Plexiform pattern.




When the diameter of anterior communicating artery is less than 1mm, it was considered as hypoplastic. Hypoplastic anterior communicating artery was found in four specimens (Fig. 14,15)

**Fig. 14:** Hypoplasia of Anterior communicating Artery.

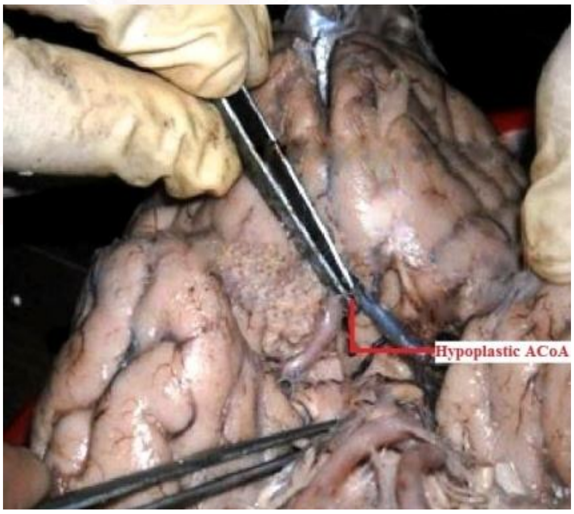



**Fig. 15:** Hypoplasia of Anterior communicating Artery.

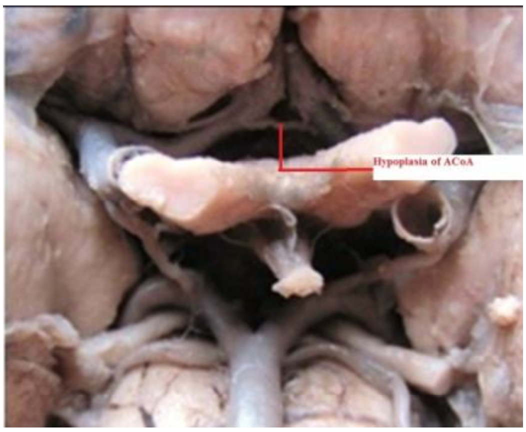


**Table 1:** Anatomical variations.

| Variation type | Number of Variations | Percentage % |
|---|---|---|
| Complete and normal CW | 54 | 72% |
| CW gross variations | 30 | 40% |
| Incomplete CW | 8 | 10.66% |
| ACA - A1 Segment | 8 | 10.66% |
| ACoA | 13 | 17.33% |

**Table 2:** Symmetry of different components of Circle of Willis.

| Segment of CW | Symmetrical | Asymmetrical |
|---|---|---|
| ACoA | 62 (82.66 %) | 13 (17.33%) |
| ACA –A1 | 67 (89.33 %) | 8 (10.66 %) |

**Table 3:** Percentages of different variations of Circle of Willis.

| Components | Variations | Right | Left | Number of Specimens | % | Total | Total % |
|---|---|---|---|---|---|---|---|
| | Hypoplasia | 5 | -- | 5 | 6.66 | | |
| ACA – A1 | Aplasia | -- | 1 | 1 | 1.33 | 8 | 10.66% |
| Segment | Plexiform | -- | 1 | 1 | 1. 33 | | |
| | Accessory | 1 | -- | 1 | 1. 33 | | |
| | Duplication | -- | -- | 5 | 6. 66 | | |
| ACoA | Triplicaton | -- | -- | 1 | 1. 33 | | |
| | Hypoplasia | -- | -- | 4 | 5.33 | 13 | 17.33% |
| | Fused | -- | -- | 2 | 2.66 | | |
| | Plexiform | -- | -- | 1 | 1.33 | | |

## 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 t 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 etal(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 anterior communicating artery (17.33%) in this present study.

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 6.66%, Aplasia is 1.33% Plexiform pattern is 1.33% 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 (1888)[18] and Alpers et al (1959)[4] who recorded 3% and 2% cases of absence of the ACOM due to fusion of the two anterior cerebral arteries respectively. 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 (1905) [19] who found complete absence of anterior communicating artery in 0.14% cases. 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 [23] used 1.5 mm as the cut off value. They found 10% of the brains to have less than 1.5 mm in diameter in the aforesaid segment. Alpers *et al* (1959) [5] found string like components of one of the vessels of the CW in 28% cases, with that part of ACA being the predominant site.

Riggs and Rupp (1963) [6] observed hypoplasia of that part of ACA in 7% cases. Plexiform anterior cerebral artery is a very rare occurrence. 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 [24, 20]. In our 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 (17. 33%), 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 6.66% 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 [27], PN Jain [28] and Vare and Bansal [29]. The absence of anterior communicating artery was observed in 2.6% of subjects. Fawcett and Blachford [19], Blackburn [30], Von Mitter wallner [31], Kanchan Kapoor [27], PN Jain [28] and Vare and Bansal [29] found same variation, but less frequently, to range from 0.14% to 1.8%, as compared to that in the present study. 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 [18], Stopford [30]. The old author using the term fistula is not convincing recent study done by Kanchan Kapoor [27] included this variation of fused anterior communicating artery as the absence of artery. Berk [33] and Stopford [32] had reported duplication of anterior communicating artery in 9% and 7.9% cases respectively. Vare and Bansal [29] mentioned in their study, that in duplication or triplication of the vessel, the posterior most arteries had a smaller size, which was similar to that which was seen in the present study. 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].

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 in the course of 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 in the course of anterior communicating artery was associated with long and straight course of the anterior cerebral artery. Similar variations were mentioned by Vare and Bansal [29], Kanchan Kapoor [27] in their study.

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 [30]. 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 [28]. 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 [31].

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 [32]. 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 [29]. 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.

## ACKNOWLEDGEMENTS

We are grateful to the HOD, Department of Anatomy, & principal of Government Medical College, Jagdalpur. And also my sincere thanks to the Principal Gouri Devi institute of Medical sciences ,Durgapur , and to the Department of Anatomy staff.

**Conflicts of Interests: None**

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**How to cite this article**:

Ajay Babu Kannabathula, Gunjan Rai, Himadri Sunam. ANATOMICAL VARIATIONS OF ANTERIOR CEREBRAL ARTERY AND ANTERIOR COMMUNICATING ARTERY: A CADAVERIC STUDY. Int J Anat Res 2017;5(2.3):3882-3890. **DOI:** 10.16965/ijar.2017.179