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A comprehensive study of magnetic resonance angiography of circle of Willis in population of Western Uttar Pradesh

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Abstract--Background: Circulus Arteriosus cerebrii, another name for Circle of Willis, establishes a polygonal anastomotic channel between two internal carotid arteries and two vertebral arteries. The arterial circle is located in the interpeduncular fossa, near the base of the brain. It has been established through anatomical and radiological studies that there are anatomical variations in healthy persons. Aim: To evaluate the anatomical variations in arteries of circle of Willis supplying brain through Magnetic Resonance Angiography (MRA) in population of western UP. Methods and Materials: This cross-sectional study included 264 patients who met inclusion criteria. Non-contrast Magnetic Resonance Angiography of Circle of Willis was carried out

among the individuals after a written informed consent. Angiography of brain (circle of Willis) scanning protocol consisted of 3-dimensional time of flight Trans axial acquisition. MRA of brain was performed on GE 1.5 TESLA Optima MRI machine. MRA Brain angiography images were viewed for normal pattern of arterial anatomy and their variations. Results: The complete variant in male was 58.9% (n=103) while in females it was 59.6% (n=53). The incomplete variant in male & females was 41.1% (n=72) and 40.4% (n=36) respectively. Overall, the complete circle of Willis was 156 in number while incomplete variant was 108. In both sexes complete variant was found to be 59.1% (n=156) while the incomplete variant was 40.9% (n=108). The proportion of incomplete anterior communicating artery in circle of Willis in male was found to be 18.9% (n=33) and 18.0% (n=16) in females. The left and right posterior communicating artery variant in males were 3.4% (n=6) and 5.1% (n=9) respectively. The left and right posterior communicating artery variant in females were 2.2% (n=2) and 5.6% (n=5) respectively. Conclusion: The morphological changes shown by TOF-MRA in our study can be an important reference source for COW [CIRCLE OF WILLIS] variations in the western UP population. Our results support the established findings by various studies that the COW configuration varies greatly in population, as found in the population of this region.

Keywords--Circle of Willis, MRA, Anatomic variations, TOF.

Introduction

Circulus Arteriosus cerebrii, another name for the arterial circle of Willis, establishes a polygonal anastomotic channel between two internal carotid arteries and two vertebral arteries. The interpeduncular fossa, near the base of the brain, is where the arterial circle is located. In 1966, Thomas Willis initially outlined the function of the Willis arterial circle. The anterior cerebral arteries and the anterior communicating artery make up the anterior part of the circle of Willis, the posterior cerebral arteries and the posterior communicating artery make up the posterior half of the circle of Willis, and the middle cerebral arteries make up the middle section.^{1,2} The morphology of the circle of Willis has a relationship with the development of cerebral aneurysms, and variations in the circle of Willis which may signal changes in brain hemodynamics that lead to various cerebrovascular diseases.^{3,4}

In patients with Internal Carotid Artery (ICA) occlusion, the COW is a crucial possible collateral channel for preserving adequate cerebral blood flow. Accurate understanding of intracranial vascular architecture is now more crucial than ever because of advancements in micro neurosurgery as well as the improved ability to treat occlusive neurovascular pathology surgically and via interventional approaches. It has been established through anatomical and radiological studies that 30% of healthy persons have COW anatomical variations. Before Magnetic resonance angiography (MRA) of brain, the arterial changes were investigated under digital contrast-enhanced angiography, transcranial Doppler ultrasound

and contrast Computed Tomography scan. In recent era of radiodiagnosis the new modalities were introduced like magnetic resonance angiography (MRA), mathematical models for examination of the arterial pattern and function of COW.^{5,6} MRA has previously been proven to be well-suited to explore the COW because it can accurately give morphological (Branches pattern of arteries) and hemodynamic information about the direction of blood flow in specific arteries. Three-dimensional time-of-flight (3D-TOF) MRA has been shown in prior research to be a sensitive, noninvasive method suited for identifying the anatomy of the CW in both healthy subjects and patients with carotid artery disease.^{7,8} This study was carried out to determine the anatomical variations of arteries of circle of Willis through MRA supplying brain in population of western UP.

Materials and Methods

This cross-sectional study was conducted in the department of radiodiagnosis, Santosh Medical College & Hospital, Ghaziabad, Rama Medical College, Hapur and Dr. O.P Gupta Imaging Centre, Meerut. Non-contrast-Magnetic resonance imaging of Circle of Willis was carried out. Before the examination of MRA, a written consent was taken from all the subjects who were included in the study. Angiography of brain (circle of Willis) scanning protocol consisted of 3-dimensional time of flight Trans axial acquisition. MRI Angiography of brain was performed on GE 1.5 TESLA Optima MRI machine. MRA Brain angiography images were viewed for normal pattern of arterial anatomy and their variation study from June 2019 to Nov 2021. (Figure A,B,C,D). This study was carried out among 264 patients who met the inclusion criteria after getting the written informed consent. The study was approved by Institutional ethics committee.

MRA (brain) protocol scan technique

A head surface coil was used for brain angiography. The Magnetic resonance angiography protocol consisted of non-contrast 3- dimensional time of flight trans axial acquisition which was used for examination of all patients with the following parameters - rectangular field of view (FOV) 200 -220 mm, matrix size 520 -560 with slice thickness of 0.6 -8 mm and 150 partitions with the total imaged volume (effective slab thickness) 70-75 mm. Time Reptation - 22-25 /Time Echo - 6.50ms. For best resolution in imaging, slice thickness was used using matrix size 192 x 256. (MIP).

Results

There was evaluation of distribution of complete and incomplete variants according to the gender as shown in table 1,2,3. The complete variant in male was 58.9% (n=103) while it was 59.6% (n=53) in females. The incomplete variant was 41.1% (n=72) in male while it was 40.4% (n=36) in females. Overall, the complete circle of Willis was 156 in number while incomplete variant of Circle of Willis was 108. In both sexes complete variant was found to be 59.1% (n=156) while the incomplete variant was 40.9% (n=108). The proportion of incomplete anterior communicating artery in circle of Willis in male was found to be 18.9% (n=33) and 18.0% (n=16) in females. The left and right posterior communicating artery variant in males were 3.4% (n=6) and 5.1% (n=9) respectively. The left and right

posterior communicating artery variant in females were 2.2% (n=2) and 5.6% (n=5) respectively.

Table 1
Distribution of variation of Circle of Willis according to gender

Sex	CIRCLE OF WILLIS		Total
	COMPLETE	INCOMPLETE	
MALE	103(58.9%)	72(41.1%)	175 (100%)
FEMALE	53(59.6%)	36(40.4%)	89(100%)
Total	156 (59.1%)	108(40.9%)	264(100%)

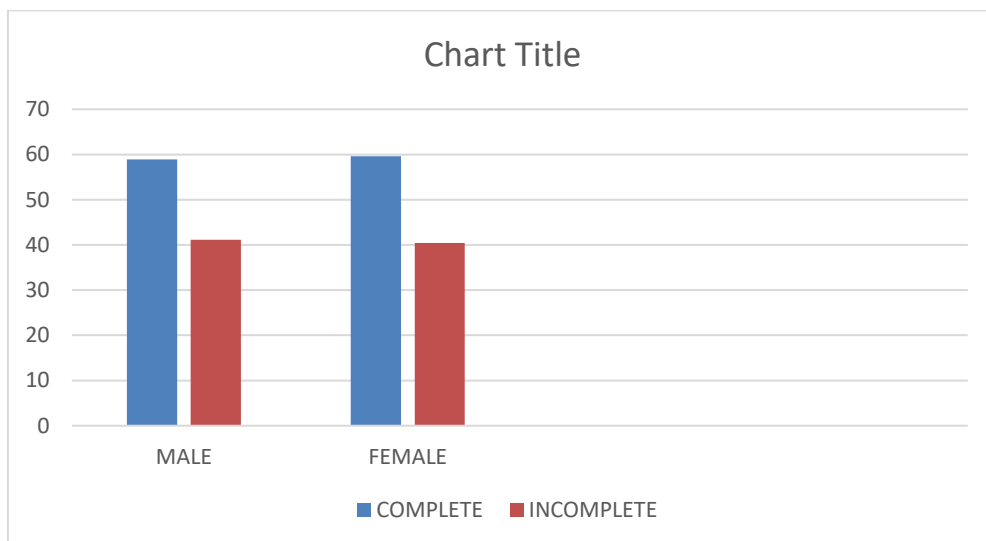


Table 2
Anterior communicating artery (A.com.) in male and female.

SEX	A.com. Artery		Total
	ABSENT	PRESENT	
MALE	33(18.9%)	142 (81.1%)	175(100%)
FEMALE	16(18.0%)	73(82.0%)	89(100%)
Total	49(18.6%)	215(81.4%)	264(100%)

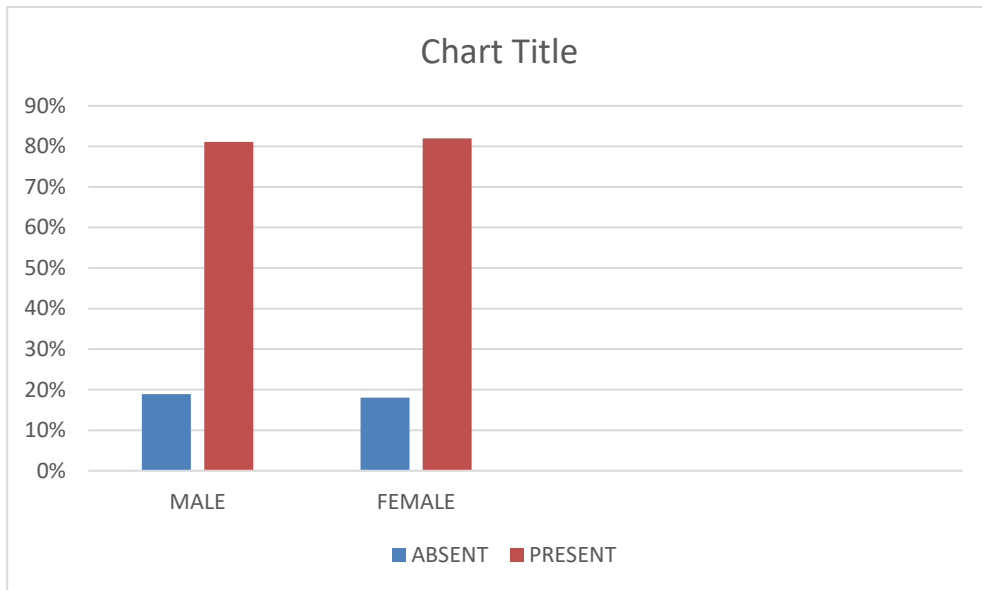


Table 3
Posterior communicating artery (P.com.) in male and female

SEX	P.Com. Artery		
	LEFT ABSENT	RIGHT ABSENT	Total
MALE	6 (3.4%)	9(5.1%)	175 (100%)
FEMALE	2 2.2%	5 5.6%	89 (100%)
Total	8 3.0%	14 5.3%	264 (100.0%)

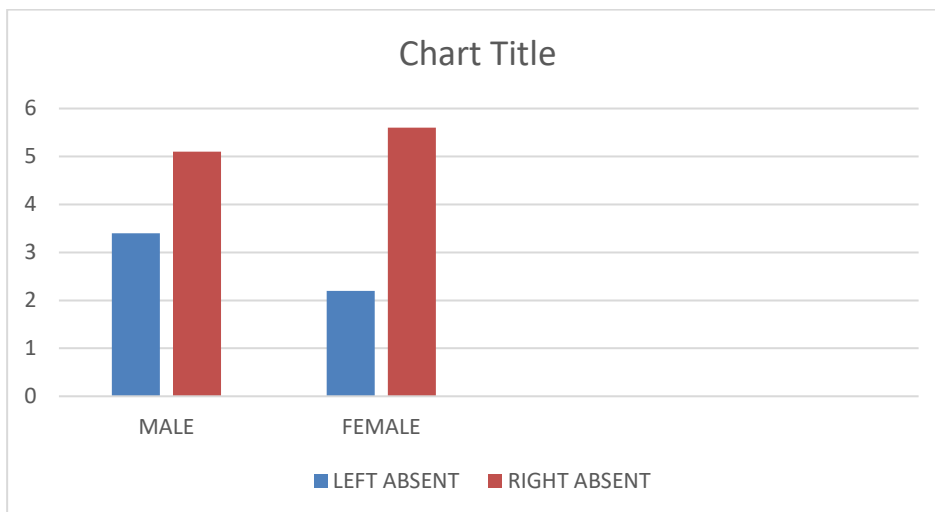


Figure A. Circle of Willis (COW)

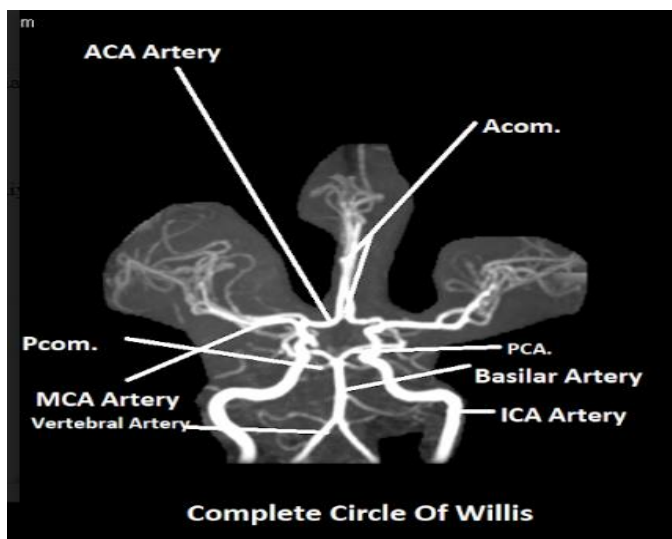


Figure B. Complete circle of Willis (Magnetic Resonance Angiography image MRA)

- ICA- (Internal carotid artery)
- ACA- (Anterior Cerebral Artery)
- PCA - (Posterior cerebral artery)
- MCA- (Middle cerebral artery)
- A.com. - (Anterior Communicating Artery)
- P.com. - (Posterior communicating artery)

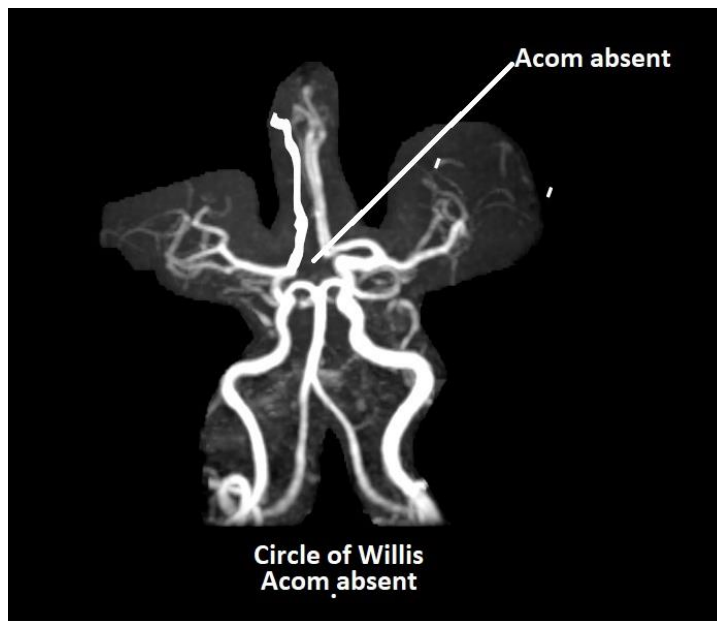
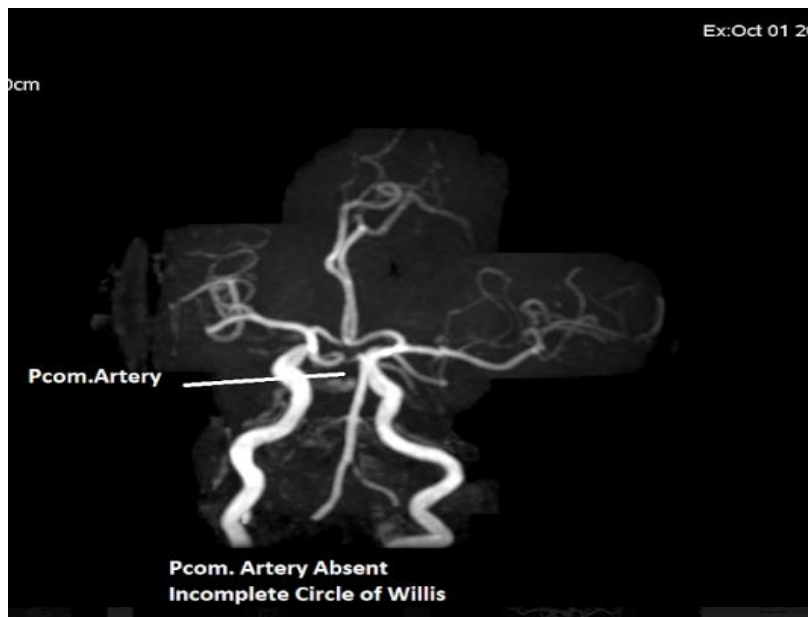


Figure C. Incomplete Circle of Willis (Absent Anterior communicating artery)



Discussion

Recent studies focused into the role of the COW in the establishment of collateral flow in ICA and vertebral artery and also variation in arterial pattern. Magnetic resonance angiography, transcranial Doppler ultrasound and digital contrast enhanced angiography (DCA) which is using for imaging of arterial pattern of brain. Through MRA, this study was conducted to identify the structural variations of the circle of Willis arteries supplying the brain in the population of

western Uttar Pradesh. Numerous anatomical and clinical investigations have looked into how the COW is configured. Only a few studies exist that have extensively examined the morphological arrangement of abroad populations. COW Of MRA has shown significant sensitivity in the assessment of components of COW vessels. However widely accepted clinically, 3D time-of-flight (TOF) MRA sensitivity is dependent on the vessel's blood flow rate, and the method may have trouble recognizing small boats in the CW with turbid or slow flow.^{9,10}

Our research focuses on COW anatomical variations. The complete variant in male was 58.9% (n=103) while it was 59.6% (n=53) in females. The incomplete variant was 41.1% (n=72) in male while it was 40.4% (n=36) in females. Overall, the complete circle of Willis was 156 in number while incomplete variant of Circle of Willis was 108. In both sexes complete variant was found to be 59.1% (n=156) while the incomplete variant was 40.9% (n=108). The proportion of incomplete anterior communicating artery in circle of Willis in male was found to be 18.9% (n=33) and 18.0% (n=16) in females. The left and right posterior communicating artery variant in males were 3.4% (n=6) and 5.1% (n=9) respectively. The left and right posterior communicating artery variant in females were 2.2% (n=2) and 5.6% (n=5) respectively.

The vessels that make up the COW were taken into consideration during the evaluation process, much like in past research. Similar to our finding, prior research found that between 74 and 90 percent of people in various ethnic groups had a complete anterior circle. Autopsy studies, on the other hand, revealed a reduced frequency of complete circles. Another recent cadaveric study reported variation of COW in 30% cases, with highest variation in P.com artery (40%) and A.com Artery (40%). Prior research has revealed a higher likelihood of complete circles in female subjects and younger subjects. Diameter of the proximal arteries evaluated on MRA in control studies tends to be larger in male and shows a tendency to diminish with progressing age.¹¹⁻¹³ Our findings are consistent with earlier research. The average age of the male and female subjects was 54.4 years and 48.6 years respectively, which may help to explain why female subjects displayed higher levels of visualization. In a large study of patients from the Indian subcontinent, Kapoor et al. found that 45.2% of them followed the conventional pattern. There were variances among the research group as a whole.^{14,15}

According to a recent cadaver study, there are 21 distinct COW variants. We have adhered to Chen et al classifications in order to create a simple scheme. There are ten distinct iterations of the anterior and posterior circles, running from A to J. One common variation entails a significant ipsilateral P com A and a relative narrowing of the posterior cerebral artery's (PCA proximal) part, allowing the ICA to serve the posterior cerebrum.^{16,17} Complete COW was seen in 4.0 - 72. Percent of other studies in autopsy studies, the incidence of complete COW ranges from 15.3 to 52.3 percent; this is significantly lower than clinical observation. There are a number of factors that could explain this discrepancy. The first is the difference in subject selection; some studies included healthy volunteers along with additional participants without vascular diseases or even some with neurological condition. The second reason can be because of the different observational techniques, such as in studies where TOF and phase-contrast MR

angiography were both used. The third reason has to do with the standards established for what makes up a complete-circled arrangement.^{18,19}

When evaluating the prevalence of different anatomical variants, we used the criterion of the vessel diameter smaller than 0.8 mm as absence.⁶ Some autopsy studies set a lower limit of 1 mm. The TOF-MRA technology has drawbacks despite its excellent sensitivity in identifying cerebral arteries. Even if the arteries are patent, slow as well as turbulent flow may not be visible in the TOF MRA images. As a result, it's possible to understate the frequency of the whole formation of circles. Twenty two percent of the time, the circle is not completely configured. A single major ICA feeding many cerebral artery regions with limited collateral flow from other arteries should be carefully noted among these variations. When a temporary or permanent closure of the parent artery is predicted, this variation—known as isolated circulation—is a significant finding for preoperative surgical planning.²⁰

In this situation, the danger of ischemia injury in the watershed region between these differentially perfused areas would result from the transient blockage of the ICA undergoing carotid endarterectomy. There have been theories put forth as to why the portions of the CW vary. The two primary explanations are postnatal maturation of the brain after occlusive disorders and genetic variables. It is remarkable from an evolutionary perspective that different cerebral arteries appear to occur equally frequently in humans and animals. In our cohort, 5% of people had posterior circles of the transitional kind²¹. We also noticed an interestingly increased prevalence of posterior variants in the research population. We think that in order to better understand regional variances, more extensive population-based research is required in light of the observed variations. In a large study with groups of subjects from north India, intracranial saccular aneurysms were found in 1% of cases and AVMs in 1.4 % of PCAs. In our study, 2% of participants had aneurysms that were acknowledged in both the left ACA and the A com A. In one case (0.33 percent), AVMs were discovered in the right side parieto occipital area. Another patient had ongoing left trigeminal artery involvement.²² Thus; our findings are consistent with those of past research.

Conclusion

The present study has shown that anatomical variants of the circle of Willis through MRI angiography in western U.P patients. This Study reveals that the variation of circle of Willis is more males in comparison to females. Anterior communicating artery and posterior communicating artery were absent more in males compared to females. The arterial variation of circle of Willis is very helpful for neuro-physician and neurosurgeon for planning and performing the open neurosurgery and laparoscopic neurosurgery. This study is important reference source for COW variations in the western UP population.

Conflicts of Interests: None

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