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## Normal Variants of Circle of Willis in MR Angiography among Puducherry Population

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### Abstract

**Introduction:** Circle of Willis is the great arterial anastomotic ring at the base of the brain and is an important pathway to maintain adequate blood supply to the brain. In case of arterial occlusion, it is the important source of collaterals to the occluded territory. A detailed knowledge of the normal anatomy of circle of Willis, its anomalies and clinical significance helps the neurosurgeon for planning and keeps away from vascular trauma during surgeries.

**Materials and Methods:** A retrospective study was conducted on 312 patients (188 men and 124 women). 3 dimensional time of flight Magnetic resonance angiogram technique was used. Variations in the Circle of Willis were evaluated.

**Results:** The findings show that majority of circle showed anomalies. Percentage of complete circle was slightly higher in males and young subjects. Normal variants are more common in anterior part of the circle and the most common normal variant is the absent anterior communicating artery (34%).

**Conclusion:** Magnetic resonance angiogram is the sensitive technique for detecting the anatomy of Circle of Willis. Variations in anterior circulation may be asymptomatic and may reduce complications. Knowledge of the presence of Circle of Willis and its variants plays an important role in planning of neurological procedures or may be mistaken for pathologies.

Keywords: Anomalies, absent anterior communicating artery, 3-dimensional time of flight.

#### Introduction

The human brain represents 2% of body weight. It is supplied by two major arteries, paired internal carotid arteries and vertebral arteries. These vessels form an anastomosis among their branches to supply the various parts of brain and its coverings which is commonly called circle of Willis named after Dr. Thomas Willis who first described the function of arterial anastomosis in 1966. Arteries forming the circle are Internal Carotid Artery, Anterior cerebral and Anterior communicating arteries, Posterior cerebral and Posterior communicating arteries. Based on recent anatomical<sup>[9,10,11]</sup> and radiological studies <sup>[12,3,14]</sup> it has been proved that normal variations in Circle of Willis are more common in healthy individuals. These variations occur during the process of vasculogenesis. Many studies have been carried out to assess the different variants various methods including using autopsy. Angiography and Magnetic resonance imaging. Knowledge of the presence of normal variants such as fenestrations, duplications, and persistent fetal arteries plays an important role in the diagnosis of arterial malformations and helps in surgical planning<sup>[1]</sup>.

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MR angiography is used in various institutions for initial evaluation of the cerebral circulation. It is also used in assessment of patients with acute stroke and subarachnoid haemorrhage. It is a noninvasive procedure and does not require any contrast injection. The aim of this study was to assess the normal variants of the Circle of Willis in patient who underwent MRI Brain for various reasons.

### **Materials and Methods**

A retrospective study was undertaken in the Department of Radio diagnosis of SMVMCH, Puducherry. Patients who were included in the study were those who underwent MRI brain as a part of their health check-up was included in this study. Clearance from Institutional Ethical committee was obtained for this study. Patients with clinical manifestations of cerebrovascular accidents, metallic aneurysm clips, cardiac pacemakers and other metallic implants were excluded. The study included subjects of all age and gender in Puducherry. The 3-dimensional time of flight MR angiograms of Circle of Willis of 312 patients at random were considered for the study. They were aged between 12 and 75 years.

### Scan technique

All the patients were examined with 3dimensional time of flight Magnetic resonance angiography. The study was performed with 1.5 tesla MR machine (Intera, Philips medical systems). A standard head coil was used for Magnetic angiography. The resonance angiography protocol consisted of non-contrast 3dimensional time of flight transaxial acquisition which was used for examination of all patients with the following parameters (TR /TE /FA (25 /6.91ms /20). Rectangular field of view (FOV) 200 mm, matrix size 560 with slice thickness of 0.8 mm and 160 partitions with the total imaged volume (effective slab thickness) 72 mm. To obtain the best resolution in the section selection direction, the smallest possible slice thickness was used using matrix size 192 x 256; this resulted in an anisotropic voxel size of 0.503 x 0.88x 0.5

mm<sup>3</sup> in plane resolution and 0.8 mm slice thickness. The post-processing algorithm, maximum intensity projection (MIP) was used to produce angiographic-like images at 5 degree increments generating 12 MIP projections. The study participants were divided into two groups based on their age, i.e. those who were < 40 in one group and  $\geq$  40 as another. The variants were analysed based on the following criteria:

- Normal presence of complete circle
- Absent anterior communicating artery
- Hypoplastic A1 segment under development of A1 segment
- Absent A1 segment
- Others variants like azygous anterior cerebral artery, unilateral fetal type PCA, bilateral fetal type PCA and combination of variants.

Figure 1 Three dimensional time-of-flight magnetic resonance (MR) angiogram of the normal CW



**Figure 2:** Three dimensional time-of flight magnetic resonance (MR) angiogram of the Absent anterior communicating artery



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**Figure 3:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Hypoplasia of A1 segment



**Figure 4** Three dimensional time of flight magnetic resonance (MR) angiogram of the Absent A1 segment:



**Figure 5:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Azygous anterior cerebral artery:



**Figure 6:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Trifurcation of anterior cerebral artery:



**Figure 7:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Fenestration of A1 segment



**Figure 8:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Bilateral fetal type Posterior cerebral artery



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**Figure 9:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the ACA forms a common trunk and split distally into two communicating segments



**Figure 10:** Three dimensional time-of-flight magnetic resonance (MR) angiogram of the Unilateral fetal type Posterior cerebral artery and hypoplasia of contral at posterior communicating artery



#### Results

In this present study we have studied retrospectively angiographic findings of Circle of Willis in 312 cases of which 188 (60.25%) were males and 124(39.75%) were females. Among the cases studied anatomical variations in anterior cerebral circulation was detected in 178 cases. posterior cerebral circulation in 28 cases and normal classical pattern in rest 106 cases. In present study we found absent anterior communicating artery in 110 cases (34%), absent A1 segment in 33 cases (10.9%), hypoplastic A1

segment in 31 cases (9.7%), and other anomalies (fenestrations, duplications, azygous anterior cerebral artery, Trifurcation of anterior cerebral artery, Bilateral fetal type Posterior cerebral artery, Anterior cerebral artery forms a common trunk and split distally into two communicating segments, Unilateral fetal type Posterior cerebral artery).

On analysing the parameters the commonest variant reported was absent anterior communicating artery. This finding was observed more in the age group  $\geq 40$  years. No significant difference was noted with regard to gender (the percentage of variants other than the normal were 65.34% in males and 65.17% in females).The percentage of normal variants was 69.56%(34.66% in males and 36.9% in females) which is in agreement with the other studies.

### **Gender Distribution**

It was found that there was mild increase in the normal variants in male when compared to females. Out of the 312 patients taken up for this study, male were found to be 188 (60.25%) and female were found to be 124 (39.74 %)

### Male

**Table 1** shows the percentage of normalvariations in male population

Variants	<40 years		$\geq 40$ years	
Normal	34	40.47%	30	28.84%
Absent anterior	23	27.38%	45	43.26%
communicating				
Hypoplastic A1	06	7.14%	12	11.53%
segment				
Absent A1 segment	09	10.71%	07	6.73%
Others	12	14.28%	10	9.61%
Total	84		104	

#### Female

**Table 2** shows the percentage of normalvariations in female population

Variants	<40 years		$\geq 40$ years	
Normal	18	39.13%	24	30.76%
Absent anterior	13	28.26%	29	37.17%
communicating				
Hypoplastic A1	04	8.69%	09	11.53%
segment				
Absent A1 segment	05	10.86%	12	15.38%
Others	06	13.04%	04	5.12%
Total	46		78	

### Discussion

Thomas Willis (1621-1675) in his book Cerebri Anatome in 1664, the history of the arterial Circle of Willis goes back to Hetrophilus, who discovered a structure which he called as 'retemirabile'; later on, Galen mentioned that the carotid arteries run in the neck and enter the cranium and gives of two cerebral arteries to supply the brain. The first reasonable and correct description of basal arterial ramification was given by Fallopius (1523-62)except for the posterior communicating artery which he thought to be indirectly connected with the internal carotid artery through a network of small arteries. Later this mistake was rectified by Casserius (1561-1616) unilaterall. Since first described by Thomas Willis, the cerebral arterial circle has been the subject of multiple investigations<sup>[17,18].</sup>

Anatomical variations of circle of Willis in the inter peduncular at the base of the brain are very common incidental finding on MR angiographic studies. Vascular imaging with MRA or CT angiography coupled with perfusion imaging provides complementary information that is used to diagnose and make treatment decisions in acute stroke. Usually patients are asymptomatic but recognition of these variants is important for planning surgery and endovascular treatment planning. Even though they are clinically insignificant some may predispose the patient to development of aneurysms or ischemic events.

In this study, it is demonstrated that the percentage of entire complete circle of Willis was seen in 34.8%, this results cope with the results of published studies by krabbe et al <sup>[4]</sup>and Hafez KA<sup>[8]</sup> et al which showed complete circle in 36% and 45%. The anterior circle configurations were complete in 30.12 % of cases in this study, and results reported by other studies shows 68–78%. Several factors influence the variations in the results. First, the study populations differ (studies performed in normal brain versus those performed in patients with CVA). Second the different methods and technique used such as anatomic dissection at autopsy versus conventional catheter

angiography, versus phase contrast or TOF MR Angiography. Third, the variations in the age and gender distributions in the selected study population. In our study, complete circle of Willis was higher in age group of <40 yrs than in the age group >40yrs which has been in line with other studies. The percentage of the complete circle >40yrs in our study was higher in females (30.76%) than males (28.84%) these results cope with the results of published studies by Hafez et al, Chen et al ,and Hartkamp et  $al^{[8,7,4]}$ . All of these studies used 3-dimensional time of flight Magnetic resonance angiography in examination of the circle of Willis. There are some limitations in displaying small collateral channels because of the turbulent flow, saturation effect of slow flow or long in-plane flow, or slower velocity of blood adjacent to the wall due to laminar flow <sup>[15]</sup>.Since an increase in flow velocity improves signal intensity which increases the sensitivity of 3dimensional time of flight Magnetic resonance angiography in detection of small communicating vessels. Negligible or slow flow within a patent vessel or vessel aplasia are not visualized on a time of flight Magnetic resonance angiography. The lower limit of normal vessel diameters is arbitrary and affects the number of vessel segments classified as hypoplastic, which also affects the prevalence of circles, defined as complete<sup>4,16].</sup>

### Conclusion

The study shows that variants are not uncommon. Anterior communicating artery complex is the most frequent site of intracranial aneurysms frequently present with subarachnoid haemorrhage. Due to its angio architecture and flow dynamics of the anterior communicating artery region, frequent anatomical variations, deep inter hemispheric location, and danger of severing the perforators with ensuing deficits. Knowledge of the presence of normal variants plays an important role in the diagnosis of arterial malformations and helps in surgical planning.

### References

- Dimmick SJ, Faulder KC. Normal variants of the cerebral circulation at multidetector CT angiography. Radiographics. 2009; 29: 1027–43.
- Kondori BJ, Azemati F, Dadseresht S. Magnetic Resonance Angiographic Study of Anatomic Variations of the Circle of Willis in a Population in Tehran. Arch Iran Med. 2017; 20(4): 235 – 239.
- Naveen SR, Bhatt V, Karthik GA. Magnetic resonance angiographic evaluation of Circle of Willis: A morphologic study in a tertiary hospital set up. Annals of Indian academy of neurology.2015; 391-397.
- Krabbe Hartkamp MJ, Van dergrond J. Investigation of the circle of Willis using MR angiography. Medicamundi .2000; 44(1): 20 -7.
- Lippert H, Pabst R. cerebral arterial circle (circle of willis) . In:Lippert H, Pabst R, editors. Lippert H, Pabst R, editors. Arterial variations in man: classification and frequency. Bergmann: Munich, Germany; 1985. p. 92–3.
- Haripriya M, Melani RS, A study of the anatomical variations of the Circle of Willis using Magnetic Resonance Imaging: International Journal of Anatomical Sciences: 2010: 1: 21 – 25.
- Chen HW, Yen PS, Lee CC, et al. Magnetic resonance angiographic evaluation of circle of Willis in general population: a morphologic study in 507 cases. Chin J Radiol 2004; 29:223–9.
- Hafez KA, Afifi NM, Saudi FZ. Anatomical variations of the circle of Willis in males and females on 3D MR angiograms. Egyptian J Hospital Med 2007;26:106–21.
- 9. Alpers BJ, Berry RG, Paddison RM. Anat omical studies of the circle of Willis in nor

mal brain. AMA Arch Neurol Psychiatry 1959;81:409-18.

- Ozaki T, Handa H, Tomimoto K, Hazama F. Anatomical variations of the arterial sys tem of the base of the brain. Arch JpnChir 1977;46:3-17.
- 11. Kapoor K, Singh B, Dewan LI. Variations in the configuration of the circle of Willis. Anat Sci Int 2008;83:96106
- 12. Macchi C.etal Magnetic resonance evaluation of angiographic circulus arteriosus cerebri (circle of Willis): A morphologic study in 100 human healthy subjects. Ital J Anat Embryol 1996;101:115-23
- 13. Jongen JC, Franke CL, Soeterboek AA, Ve rsteege CW, Ramos LM, van Gijn J. Blood supply of the posterior cerebral artery by t he carotid system on angiograms. J Neurol ogy 2002;249:455-60.
- 14. Papantchev V, Hristov S, Todorova D, Naydenov E, Paloff A, Nikolov D, etal. Some variations of the circle of Willis, importat for cerebral protection in aortic surgery - A study in Eastern Europeans. Eur J Cardiothoracic Surg 2007;31:982-9
- 15. Lee JH et al. relationship between circle of willis morphology on 3D time of flight MR angiograms and transient ischemia during clamping of internal carotid. Artery during carotid endarterectomy. AJNR2004;25:558-64.
- 16. Brunereau LO, Levy C, Arrive L. Anatomie du polygone de Willis en ARM 3d temps devolavecanalyse des patitions. J Radiol 1995;76:573–5.
- 17. William AN. Thomas Willis' understanding of cerebrovascular disorders. J Stroke Cerebrovasc Dis 2003;12:280-4. DOI: 10.1016/ j.jstrokecerebrovasdis.2003.09.012.
- Ustun C. Dr. Thomas Willis' famous eponym: the Circle of Willis. Turk J Med Sci 2004;34:271-4.