

Anatomical Variants of Circle of Willis in South Indian Population: A Study by Using Magnetic Resonance Angiography

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Abstract: ***Objectives:** To evaluate and to describe the prevalence and pattern of circle of Willis (CoW) arterial variants (aplasia, hypoplasia) and anomalies {arteriovenous malformations (AVMs), and aneurysms} in non-contrasted three-dimensional time-of-flight MR angiography (3D-TOF-MRA) in general population. **Methodology:** A cross sectional study was undertaken in the Department of Radiology of NarayanaHrudayalaya Institute of Medical Sciences, Bangalore. About 300 healthy participants (198 men, 102 women) during the study period constituted the study sample. **Results:** The prevalence of complete configuration of the circle is 16.6% and is slightly higher in females than males and younger (below 50 yrs) than older subjects. In the present study the complete anterior circle of Willis is common with 77.3% of all the subjects. The commonest anterior circle variant is type A (normal anterior configuration) with a prevalence of 66%. The most common posterior circle variant is type E (Hypoplasia or absence of both PcomAs and isolation of the anterior and posterior parts of the circle at this level) with 32.6%. **Conclusion:** Overall, circle of Willis variants are slightly more common among the women in comparison to men. Incidences of associated anomalies, like aneurysm or AVM are comparable to that described in literature.*

Keywords: prevalence, circle of Willis, arterial variants, anomalies, MR angiography.

1. Introduction

The Circle of Willis (CW) is an important anatomical part formed by the anastomosis of internal carotid and vertebral basilar systems. It is located at the base of brain and acts as an important pathway to maintain adequate flow of blood to the brain in conditions such as internal carotid artery (ICA) obstruction. The importance of this anastomosis is of great significance in case of obstruction of one of the major arteries of brain.^{1,2} The neurovascular deficits mainly depends upon the severity of occlusion of the major artery supplying the brain and ability of the patient to withstand with this occlusion. The variations in the calibre of the communicating arteries are important in influencing the hemodynamics of Circle of Willis.³ The contributions from the flow rates proximal arteries correlate significantly with the anatomical variations of the Circle of Willis.⁴ The collateral pathways of Circle of Willis maintains the blood flow to the deprived side of the brain. The presence, size of the component vessels, Individual morphological and hemodynamic factors influences the development of such collateral pathways.^{5,6} The studies available have shown the anatomical variations of the Circle of Willis.^{7,8}

The volume flow rates of the feeding arteries are often used by the radiologists to measure the blood dynamics in patients with vascular diseases. The anatomic variations of Circle of Willis are known to affect these volume flow rates. The studies have shown a direct relation between the anatomical variations in the Circle of Willis and volume flow rates in the internal carotid arteries and the basilar artery.^{9,10} However, such studies are scant in South India. It has been demonstrated from the studies available that the Magnetic resonance Imaging is a sensitive and non invasive imaging tool to evaluate the anatomy of Circle of Willis in

normal healthy volunteers and patients with cerebral artery disease. Hence, this study was undertaken in a tertiary care centre in Bangalore.

2. Aims and Objectives

The purpose of this study is to evaluate and to describe the prevalence and pattern of circle of Willis (CoW) arterial variants (aplasia, hypoplasia) and anomalies {arteriovenous malformations (AVMs), and aneurysms} in non-contrasted three-dimensional time-of-flight MR angiography (3D-TOF-MRA) in general population.

3. Materials and Methods

A cross sectional study was undertaken in the Department of Radiology of NarayanaHrudayalaya Institute of Medical Sciences, Bangalore. The patients attending the Department as part of their health check up were included in the study. About 300 healthy participants (198 men, 102 women) during the study period constituted the study sample. Informed consent from the patient / attender (children/unconsciousness) was obtained before each scanning. Clearance from Institutional Ethical committee was also obtained before the study was started. All were subjected for Magnetic Resonance Imaging were scanned by using a 1.5Tesla scanner (Achieva; Philips Medical Systems) with a dedicated high-resolution 3D time-of-flight (TOF) MRA protocol with TR/TE/flip angle of 19/5.7ms/16°, respectively, and true isotropic resolution of 0.6 x 0.6 x 0.6 mm³. This protocol has been specifically optimized for use in a patient population. Standard anatomic T1- and T2-weighted images were also acquired; more specifically T1-weighted volume scans and T2-weighted multisection fast-field echo

anatomic scans were obtained for the detection of brain abnormalities.

Patients were imaged either in natural sleep or, where necessary, after sedation with midazolam 0.07 to 0.08 mg/kg IM (approximately 5 mg IM) administered upto 1 hour before the study for uncooperative patients, to prevent image degradation from motion artifacts. Each patient was positioned supine, and the head was immobilized by head coil. Additional ear protection was used for each patient. Monitoring of patients vital signs was performed throughout the scanning.

4. Results

Table 1: Gender and age distribution of the study subjects

Age group	Male n (%)	Female n (%)	Total n (%)
Less than 20 years	4 (2.0)	3 (1.5)	7 (3.5)
21 – 30	3 (1.5)	9 (4.5)	12 (6.1)
31 – 40	18 (9.1)	17 (8.6)	35 (17.7)
41 – 50	35 (17.7)	20 (10.1)	55 (27.8)
51 – 60	50 (25.3)	20 (10.1)	70 (35.4)
61 – 70	53 (26.8)	20 (10.1)	73 (36.9)
71 years and above	35 (17.7)	12 (6.6)	47 (23.7)
Total	198 (100)	102 (100)	300 (100)

All participants underwent three-dimensional time-of-flight (3D-TOF) MR angiograms of the Circle of Willis (CW) examination at our institution. Gender distribution among the subjects studied, Most of the patients were men (66%). About 36.9% of the patients belonged to 61 – 70 years age group. About 26.8% of the males and 10.1% of the females belonged to 61 – 70 years of age group. The mean age was 55 years. The oldest patient is aged 90 yr. In this study three patients had incidental aneurysms, one subject was had arteriovenous malformation and another subject had persistent trigeminal artery on MR angiograms in this study.

Table 2: Age distribution of anterior circle of Willis variants

Age	A	b	c	d	E	f	g	h	i	j
< 50 yr	78	1	3	5	3	0	15	4	0	0
> 50 yr	120	1	3	13	5	0	24	24	0	0
Total	198	2	6	18	8	0	35	28	0	0

The prevalence of the variants of the anterior part of circle of Willis for different age groups, both sexes and for total subjects are shown in Tables 2 and 3. Variant type A was the most common type of anterior part of the circle of Willis in all age groups and both sexes.

Table 3: Gender distribution of anterior circle of Willis variants

Gender	A	b	C	d	E	f	g	h	i	j
Male	127	1	3	12	5	0	27	22	0	0
Female	71	1	3	6	3	0	12	6	0	0
Total	198	2	6	18	8	0	35	28	0	0

In total, the anterior circle of Willis was complete in 232 out of 300 participants (77.3%), of whom a normal configuration was seen in 198 subjects (A). In two patients, two anterior communicating arteries were observed (b). The anterior circle was incomplete in 68 participants who had compromised anterior collateral flow, of whom the anterior communicating artery was invisible (absent) in 35 patients.

The remaining 28 subjects had A1 hypoplasia or aplasia. The most common type of anterior collateral was type A, in which all component vessels were competent.

The prevalence of the variants of the posterior part of CoW is shown for different age groups, both sexes and total subjects in Tables 4 and 5. The prevalence of unilateral FTPcomA (posterior part variants B, F, G and H) was 16% and bilateral FTPcomA (posterior part variants C, I and J) was found in 7%.

Table 4: Gender distribution of posterior circle of Willis variants

Gender	A	B	C	d	E	f	g	h	i	j
Male	22	11	7	22	69	2	19	5	0	7
Female	29	3	6	5	29	1	2	5	0	1
Total	51	14	13	27	98	3	21	10	0	8

Table 5: Age distribution of posterior circle of Willis variants

Age	A	b	C	d	E	f	g	h	i	j
< 50 yr	37	7	6	7	38	0	2	2	0	2
> 50 yr	14	7	7	20	60	3	19	8	0	6
Total	51	14	13	27	98	3	21	10	0	8

A higher percentage of incomplete collaterals were observed in the posterior part of the circle compared with the anterior collaterals. The most common type of posterior variation was type E, in which bilateral PcomA were absent. An adult configuration complete posterior circle was observed in 51 participants, and transitional variant was observed in 29 participants. A fetal-type posterior circle of Willis (FTP) was seen in 69 (23%) of the 300 subjects. Of the 69 subjects with FTP, 56 (18.6%) were classified as having partial FTP in which a hypoplastic P1 segment was present, and 13 (4.3%) were found to have a full FTP in which a P1 segment was absent. Of the 56 participants with a partial FTP, a unilateral FTP was found in 35 participants and bilateral FTP was seen in 21 participants.

Table 6, 7 shows the prevalence of complete, partially complete and incomplete configuration of the entire circle of Willis for different age groups, both sexes and total subjects. There is statistically significant difference among different age and sex groups. Higher prevalence of complete circle of Willis was found in younger group (below 50 yr) (33.9% of younger older subjects versus 6.8% of older subjects) and in females (28.4% of women versus 10.6% of men).

In the combined analysis, a complete circle of Willis was seen in 50 (16.6%) of 300 subjects. An incomplete anterior and posterior circle of Willis was found in 66 (22%) of 300 subjects. The remaining 184 (61.3%) subjects had partially complete circle of Willis configuration. The most common type of circle of Willis in a single subject was anterior variant type A and posterior type variant E.

Table 6: Gender distribution of completeness of circle of Willis

	Complete	Partially complete	Incomplete
Male	21	129	48
Female	29	55	18
Total	50	184	66

Table 7: Age distribution of completeness of circle of Willis

Age	Complete	Partially complete	Incomplete
< 50 yr	37	53	19
> 50 yr	14	131	47
Total	51	184	66

5. Discussion

Knowledge of the presence and clinical relevance of normal variants such as fenestrations, duplications, and persistent fetal arteries plays a crucial role in the diagnosis and management of acute stroke and subarachnoid hemorrhage and may aid in surgical planning. However, the significance of normal variants diverges widely. In this study, it is demonstrated that the prevalence of entire complete circle of Willis was seen in 16.6%, another study shows complete circle of Willis in 36%.¹¹ These great variations in the results are related to several factors. First, these selected study populations differ (studies performed in normal brain versus those performed in patients with neurovascular disease). Second the 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 sex distributions in the study populations. In a recent study¹² the percentages of entirely complete circle of Willis were seen in 45% while in our study was detected in 46.7%. The anterior circle configurations were complete in 77.33% of cases in this study. The other studies are in agreement with our results showing 68–78%.^{11, 13} In our study, complete anterior circle of Willis was higher in age group of >50 yrs than in the age group < 50 yrs which has been contradicted by other studies.^{13, 14} The complete posterior circle configurations demonstrated in 17% of the study population and the results reported by other studies showed 25–52% of the cases.^{12, 13} In our study, complete posterior circle of Willis was higher Willis was higher in age group of <50 yrs than in the age group > 50 yrs which has been in line with other studies findings.^{13, 14} The prevalence of the complete circle in our study was higher in females (9.67%) than males (7%) these results cope with the results of published studies by Hafez et al, (26), Chen et al.¹³, and Hartkamp et al.¹⁴. All of these studies used 3D TOF MR angiography in examination of the circle of Willis. Although 3D TOF MR angiography has been known to have a high sensitivity and specificity for depicting the anatomy of the circle of Willis, it has 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.¹⁵ The sensitivity of 3D TOF MR in detection of small communicating vessels improves when flow through these channels increases, since an increase in flow velocity improves signal intensity. Non-visualization of vessels on a TOF MRA can be due to very slow or negligible flow within a patent vessel or due to the true absence of the vessel. 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. The mean diameter of centripetal vessels is larger than the centrifugal vessels in old individuals, while those of centrifugal tend to be smaller.^{14, 16}

6. Conclusion

The morphological variations demonstrated in our study providing an important reference value for the 3D-TOF MR angiography. Our findings show that the configuration of the CoW may vary largely in general population. The prevalence of complete configuration of the circle is 16.6% and is slightly higher in females than males and younger (below 50 yrs) than older subjects. In the present study the complete anterior circle of Willis is common with 77.3% of all the subjects.

The commonest anterior circle variant is type A (normal anterior configuration) with a prevalence of 66%. The most common posterior circle variant is type E (Hypoplasia or absence of both PcomAs and isolation of the anterior and posterior parts of the circle at this level) with 32.6%. Overall, circle of Willis variants are slightly more common among the women in comparison to men. Incidences of associated anomalies, like aneurysm or AVM are comparable to that described in literature.

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