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

Dr. Arjun Bahaddur[1], Dr. Chandan G[2]

[1]Assistant Professor, Department of Radiodiagnosis and Imaging, Shridevi Institute of Medical Sciences & Research Hospital, Tumkur.

[2]Assistant Professor, Department of Radiodiagnosis and Imaging, Basaveswara Medical College and Hospital, Chitradurga

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 vertebra 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 with stand 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 {arteriovenousmalformations (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. Allwere subjected for Magnetic Resonance Imaging were scanned by using a 1.5Tesla scanner (Achieva; PhilipsMedical Systems) with a dedicated high-resolution3D time-of-flight (TOF) MRA protocol with TR/TE/flip angle of19/5.7ms/16°, respectively, and true isotropic resolutionof 0.6 x 0.6 x 0.6 mm^3. This protocol has been specificallyoptimized for use in a patient population. Standard anatomicT1- and T2-weighted images were also acquired; more specificallyT1-weighted volume scans and T2-weighted multisection fast-fieldecho

anatomic scans were obtained for the detection of brainabnormalities.

Patients were imaged eitherin 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 degradationfrom motion artifacts. Each patient was positioned supine, andthe head was immobilized by head coil. Additional ear protection was used for each patient. Monitoring ofpatients vital signs was performed throughout the scanning.

4. Results

Table 1: Gender and age distributionof 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 patientshad incidental aneurysms, one subject was hadarteriovenous 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 2and 3. Variant type A was the most common type of anterior part ofthe 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 pateints.

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 post0erior part of CoWis 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 feta 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 prevalenceof entire complete circle of Willis was seen in 16.6%, anotherstudyshows complete circle of Willis in 36%.[11]These greatvariations in the results are related to several factors. First, theselected study populations differ (studies performed in normalbrain versus those performed in patients with neurovasculardisease). Second the methods and technique used such as anatomic dissection at autopsy versus conventional catheterangiography, versus phase contrast or TOF MR angiography.Third, the variations in the age and sex distributions in thestudy populations. In a recent study[12]the percentages of entirelycomplete circle of Willis were seen in 45% while in our studywas 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, completeanterior circle of Willis was higher in age group of >50 yrs than in the age group < 50yrswhich has been contradicted by other studies.[13, 14]The complete posterior circle configurations demonstratedin 17% of the study population and the results reported byother 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 > 50yrs which has been in line with other studies findings.[13, 14]The prevalence of the complete circle in our study was higherin females (9.67%) than males (7%) these results cope with the resultsof 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 inexamination of the circle of Willis. Although 3D TOF MRangiography has been known to have a high sensitivity andspecificity for depicting the anatomy of the circle of Willis, it has some limitations in displaying small collateral channels becauseof the turbulent flow, saturation effect of slow flow orlong in-plane flow, or slower velocity of blood adjacent tothe wall due to laminar flow.[15] The sensitivity of 3D TOFMRA in detection of small communicating vessels improveswhen flow through these channels increases, since an increasein flow velocity improves signal intensity. Non-visualizationof vessels on a TOF MRA can be due to very slow or negligibleflow within a patent vessel or due to the true absence of thevessel. The lower limit of normal vessel diameters is arbitraryand 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 largerthan the centrifugal vessels in old individuals, while those ofcentrifugal 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.

References

[1] Eastcott HHG. The beginning of stroke prevention by surgery. CardiovascSurg 1994;2:164–9.
[2] 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.
[3] Alnæs MS, Isaksen J, Mardal KA, et al. Computation of hemodynamics in the circle of Willis. Stroke 2007;38:2500–5.
[4] Tanaka H, Fujita N, Enoki T, et al. Relationship between variations in the circle of Willis and flow rates in internal carotid and basilar arteries determined by means of magnetic resonance imaging with semiautomated lumen segmentation: reference data from 125 healthy volunteers. AJNR 2006;27:1770–5.
[5] Mull M, Schwarz M, Thron A. Cerebral hemispheric low-flow infarcts in arterial occlusive disease: lesion patterns and angiomorphological conditions. Stroke 1997;28:118–23.
[6] Miralles M, Dolz JL, Cotillas J, Aldoma J, Santiso MA, Gimenez A, Capdevila A, Cairols MA. The role of the circle of Willis in carotid occlusion: assessment with phase contrast MR angiography and transcranial duplex. Eur J VascEndovascSurg 1995;10:424–30.
[7] Hillen B. The variability of the circle of Willis: univariate and bivariate analysis. ActaMorpholNethScand 1986;24:87–101.
[8] Krabbe-Hartkamp MJ, Van der Grond J, De Leeuw FE, et al. Circle of Willis: morphologic variation on three-dimensional time of flight MR angiograms. Radiology 1998;207:103–11.
[9] Rutgers DR, Klijn CJM, Kappelle LJ, et al. Recurrent stroke in patients with symptomatic carotid artery occlusion is associated with high-volume flow to the brain and increased collateral circulation. Stroke 2004;35:1345–9.
[10] Van den Boom R, LesnikOberstein SA, Spilt A, et al. Cerebral hemodynamics and white matter

hyperintensities in CADASIL. J Cereb Blood Flow Metab 2003;23:599–604.

[11] Krabbe-Hartkamp MJ, Van der Grond J. Investigation of the circle of Willis using MR angiography. Medicamund 2000;44(1):20–7.

[12] 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.

[13] 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.

[14] Krabbe-Hartkamp MJ, Van der Grond J, De Leeuw FE, et al. Circle of Willis: morphologic variation on three-dimensional time of flight MR angiograms. Radiology 1998;207:103–11.

[15] Lee JH, Choi CG, Kim DK, et al. Relationship between circle of Willis morphology on 3D time-of-flight MR angiograms and transient ischemia during vascular clamping of the internal carotid. Artery during carotid endarterectomy. AJNR 2004;25:558–64.

[16] Brunereau LO, Levy C, Arrive L. Anatomie du polygone de Willis en ARM* 3d temps devol avec analyse des patitions. J Radiol 1995;76:573–5.

Paper ID: SUB153633

1080