Original Article

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Variations of Circle of Willis in Indian Population

Tukaram Rathod[1], Upendra Kumar Joish[2]

[1]Department of Radiodiagnosis, S Nijalingappa Medical College, Bagalkot, [2]Department of Radiodiagnosis, JJM Medical College, Davangere.

Abstract

Background: Circle of Willis(CoW) provides the crucial anastomotic vascular supply to brain, Variations of Circle of Willis are associated with high incidence of Cerebrovascular accidents. Scant data exists in Indian context on the CoW variations prevalent. Aims: To find the frequency of variations of CoW in Indian population and review literature on stroke epidemiology. Settings and Design: Prospective observational study in a tertiary care hospital. **Subjects and Methods:** A study was undertaken between January 2017 and February 2018. Apparently healthy individuals underwent 3 dimensional Time of Flight MR angiography (3D TOF MRA) imaging of circle of Willis. Anatomy of circle of Willis was evaluated on the Image volume dataset and MIP reformations. Percentage of variations of CoW was calculated and compared with the existing data. Review of literature on epidemiology and pathophysiology of stroke in India was done. Statistical analysis used: Percentage of variations of CoW calculated. **Results:** The study included 197 volunteers with a mean age of 33 years and 5 months, who underwent 3D TOF MRA. Complete and balanced CoW was seen in 37.1% of them. Posterior circulation variations were found in 58.3% and anterior circulation variations in 20.3%. Hypoplastic/aplastic Posterior communicating arteries were the commonest segmental variations. No immediate or direct correlation was found between results obtained and epidemiology of stroke in India. **Conclusion:** Variations are the rule in CoW and are more often seen in posterior circulation. Increased prevalence rates of particular variations are likely to be associated with certain patterns of cerebrovascular disease.

Keywords: 3D Time of Flight MRA, Maximum Intensity Projection, Circle of Willis, Variations, Posterior Circulation.

Corresponding Author: Dr Upendra Kumar Joish, Department of Radiodiagnosis, JJM Medical College, Davangere – 577004.

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Introduction

The incidence of neuro-vascular insults among Indians is surpassing western world causing high mortality.[1] Ability to withstand neuro-vascular insults depend on collateral circulation provided by Circle of Willis(CoW). Any variation in morphology of CoW alters the occurrence and severity of cerebrovascular disorders, treatment options and recovery.[2-8] The problem of stroke in India is significantly different from Western World in terms of epidemiology, patterns and presentation. Hence, data from Western literature is not applicable.[9-14] With the increasing availability of endovascular facilities for management of stroke, need was felt to find the variations of CoW among Indians, due to scarce data available.

Subjects and Methods

A prospective study was undertaken in the Department of Radiodiagnosis of a tertiary care hospital, during a period from January 2017 to February 2018. Prior Institutional clearance was obtained regarding ethical concerns. Apparently healthy individuals with no co-morbidities and contraindications for MRI were included in the study, after taking their informed consent. A detailed clinical evaluation was performed by the Radiologists, prior to the Imaging. Once found eligible for the study and after taking necessary precautions for MRI, the patient was positioned in the MR gantry and a head coil was placed. Survey images were taken in all the three planes. A Fluid Attenuation Inversion recovery (FLAIR) sequence was run in axial plane to screen for any abnormalities like previous infarcts, haemorrhages, intracranial space occupying lesions etc. Thereafter, 3 dimensional Time of Flight MR angiography (3D TOF MRA) imaging of circle of Willis was done using 1.5 Tesla MRI scanner (Achieva, Philips) in individuals with normal FLAIR study. The imaging parameters and protocol used for 3D TOF MRA are depicted in [Table 1]. Reconstructions were done in the Philips workstation using 3D maximum intensity projection (MIP) algorithm. Any case with poor quality of TOF MRA/MIP images was excluded from final analysis. Anatomy of circle of Willis was evaluated on the 3D TOF MRA volume dataset and MIP reconstruction images on the Philips workstation.

The circle of Willis is formed by intracranial parts of bilateral Internal Carotid Arteries (ICA) as each of them divide into the Anterior Cerebral Artery (ACA) and Middle Cerebral Artery (MCA). Bilateral Anterior cerebral arteries (A1 segments) are connected with each other by an Anterior Communicating Artery (ACoA). These connections form the anterior half (Anterior Circulation) of the Circle of Willis. Posteriorly, the Basilar Artery branches into a left

and right Posterior Cerebral Arteries (PCA). The P1 segments of bilateral PCA's complete the circle of Willis by joining the Internal Carotid system of the corresponding side, via the Posterior Communicating Artery (PCoA). [Figure 1] depicts the components of Circle of Willis in complete and balanced configuration.

Any component of Circle of Willis with a diameter of less than 1mm on volume dataset was considered hypoplastic and any component not delineated on the images was considered absent.[15] A Circle of Willis was labelled as complete or balanced, when all its components were present and none were hypoplastic. Any hypoplastic or absent component of Circle of Willis was tabulated as a variation. The obtained information was tabulated in MS Word Excel 2010 worksheet and percentage of variations of Circle of Willis was calculated. The findings were compared with the existing data among various populations of the world.

Further, studies on epidemiology and pathophysiology of stroke in India were reviewed to find if the results obtained can help understand, the peculiar patterns of stroke in India, better.

Results

The study initially recruited a total of 230 individuals, who consented to undergo TOF MRA during study period. Twenty nine of the cases, who were aged above 55 years, were excluded from the study, due to presence of previous infarcts on FLAIR images. Four cases were excluded from the study because of poor quality of images and hence effective sample size was 197 (100 males and 97 females). The mean age of the study participants was 33 years and 5 months with a maximum of 60 years and minimum of 11 years of age. The age and gender distribution of the cases is depicted in [Table 2].

In our study 62.9 % of all the individuals showed variations in the Circle of Willis and 37.1 % showed complete and balanced Circle of Willis. Maximum variations were seen in the posterior circulation segments [Figures 1-4] as compared to anterior circulation as depicted in [Table 3].

The most common posterior circulation variation was bilateral hypoplastic/absent posterior Communicating Arteries (PCoA) [Figure 1], followed by unilateral hypoplastic /absent PCoA. Percentage of individual variations among the components of circle of Willis is depicted in [Table 4].

Table 1: Imaging parameters – 3 Dimensional Time of Flight Magnetic Resonance Angiography

Parameter	Value
Repetition Time (TR)	23 milliseconds
Time to echo (TE)	7 milliseconds
Slice thickness	0.7 mm
Plane of Acquisition	Axial
Flip angle	25 degrees
Number of slices per slab	44
Slice overlap	25%
Flow direction	Feet to head with 40mm saturation at the head end
Matrix size	180x158x256

Table 2: Age distribution of cases

Age in years	No. of males	No. of females	Total	Percentage
11 – 20	35	07	42	21.31
21 – 30	54	12	67	34.01
31 – 40	01	32	33	16.75
41 – 50	-	33	40	20.30
51 – 60	-	13	13	6.59
Total	100	97	197	100

Table 3: Percentage of variations - territorial distribution

	Types of Circle of Willis	Percentage Variations observed
1	Complete & balanced	37.1% (73/197)
2	Isolated posterior circulation variations	42.6%(84/197)
3	Combined anterior and posterior circulation variations	15.7%(31/197)
4	Isolated anterior circulation variations	4.6%(09/197)

Table 4: Percentage of variations of individual components of the Circle of Willis

Components of CoW		Percentage variations observed
Anterior Circulation	Anterior Communicating Artery	6.1%(09/197)
	Anterior Cerebral Artery	10.6%(21/197)
Posterior Circulation	Posterior Cerebral Artery	5.1%(10/197)
	Posterior Communicating Artery	30.96%(61/197)
	Fetal Posterior Cerebral Artery	10.15%(20/197)
	Basilar Artery	1.5%(03/197)

Table 5: Comparison of results

	MRI studies			Autopsy studies	
	Present Study	Qui C et al.[17]	Naveen SR et al.[18]	Singh R et al.[19]	Nordon DG et al.[20]
Geographic area	India	Chinese	India	India	Brazil
Complete and balanced CoW	37.1%	7.57%	16.6%	73.33%	46%
Anterior Circulation Variations*	20.3%	21.42%	34%	22.6%	12
Posterior Circulation Variations*	58.3%	83.93%	83%	17.3%	70.4% of all variations of CoW
Common Variations	PCoA – 30.96% ACA – 10.6% Fetal PCA – 10.15%	PCoA -76% ACoA – 17%	PCoA -32.7% ACoA – 11.6%	ACoA – 13.3% PCoA – 12% ACA -9.3%	PCoA -32% Fetal PCA – 18%

*Isolated plus combined variations.

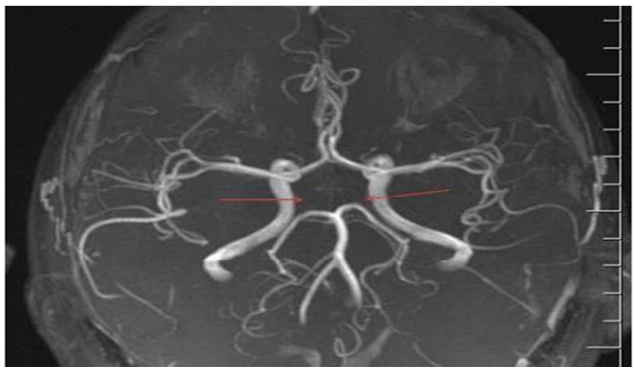

Figure 1: 3D TOF MRA MIP image of CoW showing hypoplastic bilateral PCoA (arrows).

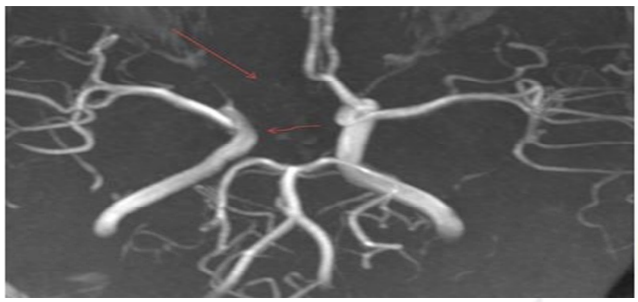

Figure 2: 3D TOF MRA MIP image of CoW – Aplastic A1 segment of Right ACA (arrow) and aplastic right PCoA (Curved arrow)

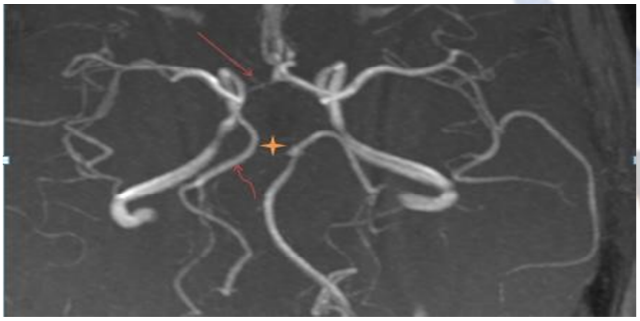

Figure 3: MIP image of 3D TOF MRA of COW– Hypoplastic Right A1(arrow), hypoplastic Right P1 (star), bilateral aplastic PCoA & Rt fetal PCA (curved arrow).

Figure 4: MIP image of 3D TOF MRA of CoW– Aplastic ACoA (thick arrow), hypoplastic Basilar Artery (star), aplastic bilateral P1 segments of PCA (thin arrows) and bilateral fetal PCAs (curved arrows).

Discussion

Circle of Willis is an anastomotic arterial arcade that provides vascular communications not only between anterior and posterior circulations but also between both the Cerebral hemispheres. Several studies have documented the significance of this communication network. Kim KM et al, concluded that people with incomplete CoW were at a risk of stroke recurrence and were likely candidates for endovascular management.[3] Zhou H et al, found that complete CoW was an independent prognostic factor for severity of stroke and incomplete variants were associated with more severe forms of stroke.[4] Nam SW et al and Songsaeng D et al, concluded that morphological variations of the CoW may lead to aneurysm formation as a result of increased shear stress on vessel walls.[6-7] Krasny A et al, found that variant A1 segment was associated with increased risk of aneurysm formation.[8] Tarulli E et al, proposed that anterior cerebral artery dominant anterior circulations are prone for recurrence of anterior communicating artery aneurysms post coiling therapy.[5] Ryan DJ et al, postulated association between variant anatomy of CoW and white matter disease due to hypoperfusion.[16]

With growing evidence on the importance of CoW, studies were undertaken to know the regional prevalences of variations of CoW and found significant interregional differences.

The results of the present study have been compared with few other recent studies in [Table 5]. As can be noted, there are fairly wide variations in the results especially in terms of prevalence of complete and balanced CoW. The present study found 37.1% cases having complete and balanced CoW, which is significantly different from other studies. Other Indian based studies like Naveen SR et al (MRI based) and Singh R et al (autopsy based) have found numbers wide apart from each other and from the present study.[18,19] A possible reason for the wide range is the diversity in criteria used to define hypoplastic vessels.

There is fair agreement between the present study and other studies regarding overall incidence of variations in anterior circulation. The present study is also in agreement with study by Qui C,[17] Naveen SR et al and Nordon et al on the commonest segment affected by variation, i.e. PCoA.[18,20] Singh R et al,[19] however found ACoA variations to be commoner.

The common underlying theme of various studies done on CoW variations has been to understand the association of such variations with increased incidence of certain types of cerebrovascular disorders in some population groups. On analysing Indian data on stroke, its found that the epidemiology of stroke in Indian context is grossly different from the western world. Mean age of patients presenting with stroke is significantly less.[12] Stroke in young adults and children and women are more common. Moreover, socioeconomic issues, access to health care and also genetic makeup differ from the developed countries.[13-14] In addition, studies in India have documented patterns and presentations of stroke significantly different from the

western world. The incidence of Haemorrhagic stroke is greater than that of the far West. Basal Ganglia and Thalami are common sites of haemorrhagic stroke.[9] Among causes of stroke in India, atherosclerosis is the commonest, followed by stroke of unknown cause, terminal vessel small infarcts, cardioembolic and vasculitis. Rheumatic heart disease is more common than in the developed world. Among stroke in young, the commonest site of vessel block is the supraclinoid internal cerebral artery, whereas extracranial vessel occlusions are more common causes of stroke in western countries.[10]

On glancing through the literature, there does not seem to be any immediate and direct correlation between the results obtained in this study and the peculiar stroke epidemiology in India. However, detailed analysis is needed to verify if these prevalence rates of Circle of Willis variations can help us to understand the occurrence of stroke, in India, better.

Conclusion

Circle of Willis, the crucial anastomotic arcade providing vascular supply to brain, shows a high frequency of variations in both anterior and posterior components, which are associated with increased incidence of various cerebrovascular abnormalities. A complete and balanced Circle is an exception, rather than the rule. Variations are more common in posterior circulation. Evaluation of Circle of Willis by MRA, prior to neurovascular intervention and surgery is essential to gauge greater risk and prognosis. A wide range of prevalence rates of different variations and normality have been reported by studies in different communities. The present study adds to the scant literature in Indian context and may help bridge gap in our knowledge on stroke epidemiology in India.

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