Assessment of anatomical variants at Circle of Willis using Magnetic Resonance Angiography among patients with suspected vascular pathology of brain in tertiary care hospital, Chennai

*** Dr. Isha Shah 1, Dr. G Murugan 2, Dr. Baskar A 3**

[1] ** Postgraduate Resident, Department of Radiology, Sree Balaji Medical College and Hospital, Chrompet, Chennai, Tamil Nadu, India. Email ID: ishah.95@gmail.com*

[2] *Head and Professor, Department of Radiology, Sree Balaji Medical College and Hospital, Chrompet, Chennai, Tamil Nadu, India. Email ID:*

[3] *Assistant Professor, Department of Radiology, Sree Balaji Medical College and Hospital, Chrompet, Chennai, Tamil Nadu, India. Email ID:*

Corresponding Author: Dr. Isha Shah
Email ID: ishah.95@gmail.com

KEYWORDS

Circle of Willis, Magnetic Resonance Angiography, Infarct, Collaterals

ABSTRACT

Introduction: Circle of Willis, is an anatomical structure that provides an anastomotic connection between anterior and posterior circulations in order to provide a collateral flow in case of any brain pathology. Vascular variations have been investigated with autopsy, Computed tomography angiography (CTA) and Magnetic Resonance Angiography (MRA) among other techniques to study blood artery morphology. By eliminating the requirement for iodinated contrast material and in certain cases, ionising radiation entirely, MRA has become a viable alternative to traditional angiography and CT angiography.

Aim and Objectives: To assess the anatomical variants at CoW using MRA among subjects with suspected vascular pathologies and additionally determine the average vessel diameter and evaluate gender related differences.

Materials and Methods: A cross sectional study was conducted in the Department of Radiology, at a tertiary care hospital, for a period of 2 years. A total of 120 cases with suspected vascular pathologies of brain (Infarct/ Haemorrhage/ Mass lesion/ signs of ischemia/ Atherosclerosis), referred to radiodiagnosis department for MRA were included in this study. All MRA brain scans were done on 3.0 Tesla G.E MRI scanner.

Results: In this study, 29.2% of participants belonged to age group of 41 – 60 years, followed by 26.7% in 61 -80 years. 56.7 % of participants were males while 43.3% of participants were females. Circle of Willis configuration was complete among 33.3% of cases, partial in 53.3% and incomplete among 13.3%. Most common type of anterior part of CoW

was A type among 52.5% of cases followed by H type among 12.5% of cases. B type and D type was seen among 10.8% and 10% of subjects respectively. The most common type of posterior part of COW was K type followed by O among 32.5% and 31.7% of cases respectively. N type was noted among 15.8 % of cases. Other types of posterior part of COW were least found in this present study.

Conclusion: Variations in CoW are common in both anterior and posterior circles and the vessel diameter in few selected vessels differ with age, gender and type of completeness of CoW. Hence, large scale studies are warranted in order to figure out the proportion of subjects with varying morphological CoW.

Introduction:

Circle of Willis (CoW), located at the base of the brain is thought to be a significant collateral channel that can help subjects with ICA blockage and maintain appropriate cerebral blood flow. The form of vessel, size and existence of its component vessels determine its capacity to redistribute the blood flow. In 1664 Sir Thomas Willis originally characterised the functions of arterial anastomosis and studies have shown the ability of CoW to create collateral flow in event of inadequate afferent supply.[1]

Two vessels confluence at the CoW, the BA and both internal carotid arteries therefore, the hemodynamics in CoW differ anatomically from those in typical branching scenarios, which are covered by the optimality principle.As a result, little is known about the typical physiology of flow and the potential effects of divergence from normalcy in CoW.[2]

The proportional contributions of flow rates of proximal arteries are highly correlated with variations in CoW.[3] Many collateral channels that redistribute blood to the side that is deprived of blood, sustain appropriate cerebral blood flow in subjects whose Internal Carotid Artery (ICAs) are blocked. These pathways develop in accordance with specific morphological and hemodynamic parameters. It is thought that the existence and size of vessels that make up the CoW affect its collateral potential.[4-6] Studies have also reported on the anatomical variability of CoW.[7-10]

Blood flow dynamics in vascular disease have been assessed using volume flow rates in the brain's feeding arteries, the ICA and the Basilar artery (BA).[11-14] The feeding arteries' volume flow rates are likely impacted by the anatomical differences in the CoW. For these frequent fluctuations, it is crucial to acquire reference volume flow rate data. The anatomical changes associated with the CoW are likely genetically determined, developing in the early stages of embryogenesis, and continuing throughout the postnatal period.[15] The most frequent anatomical abnormalities in brain blood artery morphology are related to their origins, caliber—which are frequently absent or hypoplastic. Therefore, structural deviations indicate a departure from the norm without compromising an individual's ability to perform.

Vascular variations have been investigated with autopsy, Computed tomography angiography (CTA) and Magnetic Resonance Angiography (MRA) among other techniques.

There have been several studies on this but they are based on autopsy analysis or do not fully represent the typical physiological situation due to the small sample size. Now-a-days, the advancement of imaging diagnostics has led to the proposal of techniques like MRA to study blood artery morphology.[16] MRA is used in this work to observe and classify the variances. MRA is a sensitive non-invasive technique that can be used to evaluate alterations in vivo and surveyed on large populations of healthy individuals. With these in view, this study was conducted to assess the anatomical variants at CoW using MRA among subjects with suspected vascular pathologies and additionally determine the average vessel diameter and evaluate gender related differences.

Materials and Methods:

A cross sectional study was conducted in the Department of Radiology, at a tertiary care hospital, in Chennai for a period of 2 years from October 2022 to March 2024 after approval from the ethical committee (IHEC). A total of 120 cases with suspected vascular pathologies of brain (Infarct/ Haemorrhage/ Mass lesion/ signs of ischemia/ Atherosclerosis) who were referred to radiodiagnosis department for MRA were included in this study. The study included subjects of all age groups and both the genders and who were willing to participate as subjects.

Subjects who had contraindications for MRI and poor/distorted images with artefact on MRI were excluded from the study. Subjects who met all inclusion and exclusion criteria were enrolled in this study as subjects for the anatomical variations of CoW and who were willing to participate in the relevant investigation.

All MRA brain scans were done on 3.0 Tesla G.E MRI scanner. A senior consultant radiologist was evaluating the MRA sequence pictures blindly to look for any common or unusual deviations. All the information was gathered using a data collection proforma sheet, input into Microsoft Excel, and processed using data analytic techniques.

MRA: By eliminating the requirement for iodinated contrast material and in certain cases, ionising radiation entirely, MRA is a viable alternative to traditional angiography and CT angiography.

TOF: TOF is an MRI method that allows one to see vascular flow without using contrast. It is predicated on the observation that spins entering an imaging slice exhibit flow-related amplification. These unsaturated spins produce a higher signal than the nearby stationary spins. Using 3-D TOF, phase-encoding in the slice-select direction yields a volume of images concurrently.

Results:

In this study, majority of participants (29.2%) belonged to age group 41-60 years, followed by 26.7% in the age group of 61-80 yrs. The details are shown in the following figure 1.

The mean age of study participants was 44.1± 17.5 years.

Age groups	Frequency	Percentage
≤ 20 years	15	12.5
21-40 years	29	24.2
41-60 years	35	29.2
61-80 years	32	26.7
≥ 80 years	9	7.5
Total	120	100. 0

Table 1: Age distribution of study participants

In this study 56.7 % of participants were males (n=68) while 43. 3% ofparticipants were females (n=52).

The configuration of CoW is shown in the following table 2,

Configuration	Frequency	Percentage
Complete	40	33.3
Partial	64	53.3
Incomplete	16	13.3
Total	120	100. 0

Table 2: Configuration of CoW

In our study, the most common type of anterior part of COW was A type among 52.5% of cases followed by H type among 12.5% of cases. B type and D type was seen among 10.8% and 10% of subjects respectively, while E type was seen among 8.3% of cases.G type of anterior part of COW was noted among 3.3% participants and C type among 2.5% of participants.

Similarly, the most common type of posterior part of COW was K type followed by O among 32.5% and 31.7% of cases respectively. N type was noted among 15.8% of cases. Other types of posterior part of COW were least found in this present study.

Other variants of COW were present among 6.7% (n=8) of cases in this study and absent in the remaining 93.3% (n=112) cases. Among the other variants of COW, Bihemispheric ACA was seen among 37.5% of subjects, Fenestration among 37.5% of subjects and Duplication among 25% of subjects, as shown in the following table 3,

Proportion of other variants	Frequency (N=8)	Percentage
Azygos ACA	0	0.0
Bihemispheric ACA	3	37.5
Dolichoectasia LVA & BA	0	0.0
Duplication	2	25.0
Fenestration	3	37.5
PHA	0	0.0
PTA SLTZ- Z	0	0.0
Total	8	100. 0

Table 3: Proportion of other variants

Aneurysm was present among 14.2% (n=17) of study participantshowever 85.8 % (n=103) of participants had no aneurysm.

The location of Aneurysm was anterior communicating artery (ACOA) among 58.8% (n = 1 0) of cases,MCA among 23.5% (n=4) of cases and ICA among 17.6% (n=3) of cases in our study.

In this study, the mean vessel diameter for P1 -Rt among cases who were below 40 years was 2.13± 0.37 mm and in cases above 40 years was 1.87± 0.48 mm. Posterior Communicating Artery-Rt mean vessel diameter was1.37 ±0. 41 mm among cases below 40 years and 1.56± 0.50 mm among cases above 40 years whereas the diameter of ICA -Lt vessel was 4.03 ±0.30 mm and 4.22± 0.34 mm among cases ≤40 years and >40 years respectively.

The mean difference for vessel diameter and age group for BA, PCOA-Rt and ICA-Lt was remarkable as shown in the following table 4.

Vessels diameter (in mm)	Age group		P value
	≤40 years	> 40 years	
BA	3.14±0. 25	3.23±0. 41	0.1895
P1-Rt	2.13±0. 37	1.87±0. 48	0.0024*
P1-Lt	2.11±0. 37	2.09±0. 46	0.8062
PCOA-Rt	1.37±0. 41	1.56±0. 50	0.0346 *
PCOA-Lt	1.36±0. 34	1.42±0. 39	0.3970
ICA-Rt	3.87±0. 32	3.92±0. 29	0.3828
ICA-Lt	4.03±0. 30	4.22±0. 34	0.0026 *
A1-Rt	2.14±0. 43	2.23±0. 40	0.2502
A1-Lt	2.15±0. 38	2.17±0. 34	0.7667
ACOA	1.26±0. 15	1.25±0. 16	0.7364

Table 4: Difference in vessel diameter and Age group

In this study, the difference in mean vessel diameter based on gender was significant for ICA-Lt vessel with significant p value of 0.0127 as shown in the following table 5.

Vessel diameter (in mm)	Gender		P value
	Male	Female	
BA	3.35±0. 31	3.27±0. 37	0.2004
P1-Rt	2.03±0. 33	2.11±0. 42	0.2449
P1-Lt	2.12±0. 41	2.2± 0.36	0.2668
PCOA-Rt	1.36±0. 48	1.41±0. 45	0.5624
PCOA-Lt	1.35±0. 41	1.39±0. 35	0.5741
ICA-Rt	3.81±0. 30	3.89±0. 24	0.1179
ICA-Lt	4.1± 0.35	4.25±0. 28	0.0127*
A1-Rt	2.16±0. 44	2.25±0. 39	0.2461
A1-Lt	2.12±0. 29	2.15±0. 31	0.5868
ACOA	1.25±0. 16	1.24±0. 13	0.7140

Table 5: Vessel Diameter vs Gender

The mean difference in vessel diameter for ICA -Rt and COW configuration was found to be remarkable with p value recorded as 0.045 as shown in the following table 6.

Vessel diameter (in mm)	Configuration			P value
	Complete	Partial	Incomplete	
BA	3.25 ±0. 30	3.23±0. 31	3.20±0. 23	0.764
P1-Rt	2.1± 0.36	2.14±0. 40	2.09±0. 36	0.836
P1-Lt	2.15 ±0. 44	2.3± 0.32	2.21±0. 34	0.531
PCOA-Rt	1.37 ±0. 42	1.40±0. 40	1.39±0. 39	0.673
PCOA-Lt	1.36 ±0. 39	1.37±0. 37	1.36±0. 40	0.739
ICA-Rt	3.83 ±0. 32	3.71±0. 38	3.64±0. 32	0.045*
ICA-Lt	4.14 ±0. 36	4.27±0. 26	4.13±0. 35	0.248
A1-Rt	2.14 ±0. 41	2.26±0. 35	2.16±0. 38	0.136
A1-Lt	2.10 ±0. 34	2.15±0. 35	2.15±0. 30	0.739
ACOA	1.24 ±0. 14	1.24±0. 13	1.25±0. 11	0.542

Table 6: Vessel Diameter vs COW configuration

On assessing the configuration of COW among participants ≤ 40 years of age 11.7 %, 19.2% and 5.8% of cases had complete, partial and incomplete configuration respectively. Among participants who were > 40 years of age 21.7%, 34.2% and 7.5% of them had complete, partial and incomplete configuration respectively. The association for age group and the configuration of COW was statistically not significant (p value =0. 8153).

Similarly, among male subjects 19.2% of them had complete configuration while 30% of subjects had partial configuration and 7.5% of cases had incomplete configuration. Among female subjects 14.2% of them had complete configuration, 23.3% of subjects had partial while 5.8% of subjects had incomplete configuration of COW. There was no significant association recorded between gender and configuration of COW.

Among cases with aneurysms 4.2% of cases had complete configuration, 8.3% of cases had partial configuration and 1.7% of cases had incomplete configuration. Among cases without aneurysm 29.2%, 45% and 11.7% of cases had complete, partial and incomplete configuration respectively. There was no statistical association noted for aneurysms and the type of configuration.

Based on the type of anterior part of COW, A type was the common one which was noted among 17.5% of cases who were ≤ 40 years and 35 % of cases who were > 40 years of age. B type was noted among 5 % of cases in the age group of ≤ 40 years and 5.8% off the cases in the age group of > 40 years. H type among 5% and 7.5% cases among subjects in the age of ≤ 40 years and > 40 years respectively. D type of anterior part of COW was seen among 4.2% and 5. 8% of cases respectively.

Based on the type of posterior part of COW, K type was the most common type which was noted among 10% of cases who were ≤ 40 years and 22.5% of cases who were > 40 years of age. O type was noted among 12.5 % of cases in the age group of ≤ 40 years and 19.2% off the cases in the age group of > 40 years. Other types of posterior part were least noted in both the age groups.

Likewise based on Gender A type of anterior part of COW was recorded among 30% of cases who were males and 22.5% of cases who are females. H type was seen among 6.7% and 5.8% of cases who were males and females respectively, whereas B type was found among 6.7 % of cases who are males and 4. 2% of cases among females.

In this study, based on Gender, K type of posterior part of COW was recorded among 18.3% of cases who were males and 14.2 % of cases who are females. O type was seen among 17.5% and 14.2 % of cases who were males and females respectively, whereas N type was found among 8 .3 % of cases who are males and 7.5% of cases among females. Other variants were least found among the study participants.

Images of cases with absence of right PCOM, absence of bilateral PCOM and absence of A1 segment on left and presence of fetal PCA on right are depicted below,

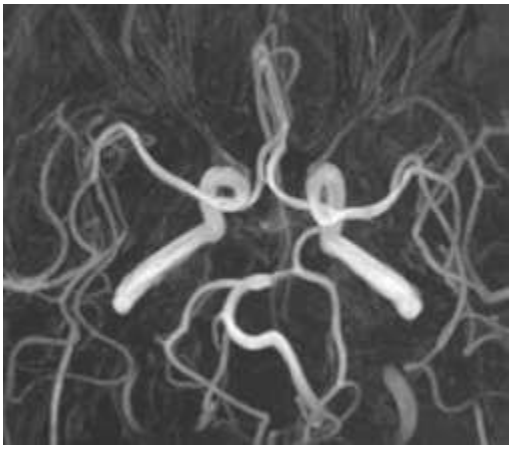

Fig 1: Absence of right PCOM

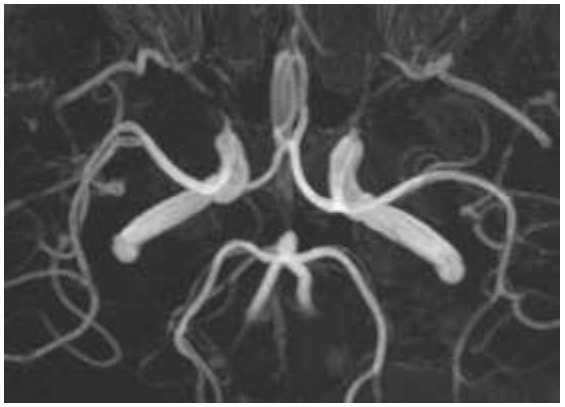

Fig 2: Absence of bilateral PCOM

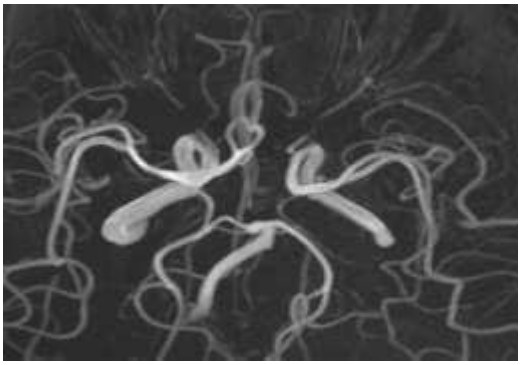

Fig 3: Absence of A1 segment on left and presence of fetal PCA on right

Discussion:

In this study 12.5% of participants were below 20 years of age, while 24.2% of participants were noted to be in the age range of 21 - 40 years. In this study 56.7% of participants were males while 43.3% of participants were females. CoW configuration was complete among 33.3% of cases, partial in 53.3% of cases while it was incomplete among 1 3.3% of cases in our study.

The most common type of anterior part of COW, in our study was A type among 52.5% of cases followed by H type among 12.5 % of cases. Similarly, the most common type of posterior part of COW was K type followed by O among 32.5% and 31.7% of cases respectively. Other types of posterior part of COW were least found in this present study. Other variants of COW were noted among 6.7% ofcases in this study.

Among the other variants of COW, Bihemispheric ACA was seen among 37.5% of subjects, Fenestration among 37.5% of subjects and Duplication among 25% of subjects. Aneurysm was present among 14.2 % of study participants however 85.8% of participants had no aneurysm. The location of Aneurysm was ACOA among 58.8% of cases, MCA among 23.5 % of cases and ICA among 17.6% of cases in our study.

In this present study, the mean vessel diameter for P1 -Rt among cases who were below 40 years was 2. 13± 0.37 mm and in cases above 40 years was 1. 87± 0.48 mm. PCOA-Rt mean vessel diameter was1.37 ±0. 41 mm among cases below 40 years and 1.56± 0.50 mm among cases above 40 years whereas the diameter of ICA -Lt vessel was 4.03 ±0. 30 mm and 4 .22± 0.34 mm among cases ≤40 years and > 40 years respectively. The mean difference for vessel diameter and age group for BA, PCOA-Rt and ICA- Lt was remarkable. In this study, the difference in mean vessel

diameter based on gender was significant for ICA- Lt vessel with significant. The mean differencein vessel diameter for ICA-Rt and COW configuration was found tobe remarkable.

On assessing the configuration of COW among participants ≤ 40 years of age 11.7 %, 19.2% and 5.8% of cases had complete, partial and incomplete configuration respectively. Among participants who were > 40 years of age 21. 7%, 34.2% and 7.5% of them had complete, partial and incomplete configuration respectively. The association for age group and the configuration of COW was statistically not significant.

Similarly, among male subjects 19.2% of them had complete configuration while 30% of subjects had partial configuration and 7.5% of cases had incomplete configuration. Among female subjects 14.2 % of them had complete configuration, 23.3% of subjects had partial while 5 .8 % of subjects had incomplete configuration of COW. There was no significant association recorded between gender and configuration of COW.

Among cases with aneurysms 4.2% of cases had complete configuration, 8.3% of cases had partial configuration and 1.7% of cases had incomplete configuration. Among cases without aneurysm 29.2%, 45% and 11.7% of cases had complete, partial and incomplete configuration respectively. There was no statistical association noted for aneurysms and the type of configuration with insignificant.

Based on the type of anterior part of COW, A type was the common one which was noted among 17.5% of cases who were ≤ 40 years and 35 % of cases who were > 40 years of age. B type was noted among 5 % of cases in the age group of ≤ 40 years and 5.8% off the cases in the age group of >40 years. H type among 5% and 7.5% cases among subjects in the age of ≤40 years and >40 year respectively. D type of anterior part of COW was seen among 4.2% and 5.8% of cases respectively.

Based on the type of posterior part of COW, K type was the most common type which was noted among 10% of cases who were ≤ 40 years and 22.5% of cases who were > 40 years of age. O type was noted among 12.5 % of cases in the age group of ≤ 40 years and 19.2% off the cases in the age group of > 40 years. Other types of posterior part were least noted in both the age groups. Likewise based on Gender A type of anterior part of COW was recorded among 30% of cases who were males and 22.5% of cases who are females. H type was seen among 6.7% and 5.8% of cases who were males and females respectively, whereas B type was found among 6.7% of cases who are males and 4.2% of cases among females.

In this current study based on gender, K type of posterior part of COW was recorded among 18.3% of cases who were males and 14.2 % of cases who are females. O type was seen among 17.5% and 14.2 % of cases who were males and females respectively, whereas N type was found among 8.3 % of cases who are males and 7.5% of cases among females. Other variants were least found among the study participants.

Findings of present study were comparable with the findings of studies like, Cavestro C etal [17] investigated abnormalities of entire CoW and their connection to vascular lesions in the brain in migraineurs in order to find any potential vascular cause of illness. In 40 % of instances, migraineurs had an anatomical variance, whereas 34 controls (21.4%) had a variant. Both MWOA and MWA significantly correlated with variations, according to their findings. Comparing unilateral posterior variations with bas ilar hypoplasia to controls, only MWA is significantly linked with them. A brain lesion of some type is present in 33% of MWOA and 24% of MWA subjects, including 2% of infra-tentorial lesions.

The presence of Circle variations was not statistically associated with either infratentorial lacunar lesions or ischemic lesions on MRI. Saikia B et al[18] used TOF-MRA to study the structural pattern of CoW in 70 healthy people from northeast India. Out of all MRAs, only 24.3% had a complete CoW. The most frequent variation found in our research (20%) was unilateral hypoplastic PCoA. Unilateral hypoplastic A1 segment of ACA was the most prevalent variant in the anterior circulation, accounting for 11.4% of cases. The majority of variant forms that were seen were consistent with previously published research. If this diversity is correlated both phylogenetically and embryologically, it can be differentiated from an abnormal architecture.

Similarly, Qiu C et al[19] reported 12.2% of COW integrity cases were overall, with 7.6 % of cases including non - variation integral COW. There were 70.2% and 17.6% of cases of partial integrity and non-integrity, respectively. Anterior circulation integrity rate was 78.58%, and it was closely correlated with the ACA- A1 developmental abnormality. The right side of ACA -A1 developmental variation rate was greater than the left side, with a rate of 28.2%. Kondori BJ et al [20] stated that 21% of subjects had a complete arterial structure in COW. 81% of cases had a complete anterior section of CoW, while 21 % of cases had a complete posterior part. The majority of variances are connected to the back of Co W. In their analysis, the prevalence of bilateral PCo A variation is higher than that of other variation types.

Additionally, Yeniçeri IO et al[21] reported that in 85% of cases, the adult configuration of Co W was identified, whereas in 13% of cases, the foetal configuration and in 2% of cases, the transitional configuration. 85.4% had a normal CoW. 62 vessels in the 14.6% of instances that were left have been found to

be agenesis. Shaikh R et al[22] identified in adults without CVD the incidence and patterns of normal structural variation of CoW on MRA. The mean age of 135 subjects was 49.3 years, with 51.8% of subjects being male and 48.2% being female. Of all the participants, 22.2% had a fully formed circle, whereas 60.7 % and 17.1 %, respectively, had partially formed andincomplete circles. In 80% of individuals, the anterior portion of circle was completed, with type ' a' being the most prevalent variety in 68.9% of cases. Of subjects, 22.2% completed the posterior portion of circle, while 38.5% had the type ' e' variant. They came to the conclusion that Pakistani individuals who were asymptomatic for CVD had a very variable architecture of CoW.

In another study, Shatri J et al [23] stated that the entire anterior portion of CW was detected in 64.3% of instances; this was more common in females (66 .2%) than in males (62.2%). Agenesis or hypoplasia accounts for 5.7% of morphologic variants of ACA1, fusion of ACAs on a short distance (6. 5%), and fusion of ACAs on a long distance (2 .5 %). Zaki SM et al [24] stated that complete, partially complete, and incomplete COW were found in 28%, 38%, and 34% of cases examined in the Egyptian population. 34% of respo ndents discovered the incomplete anterior circle, while 62% discovered the incomplete posterior circle. There were seven different anterior circle variations. With a frequency of 56%, the classical type " a" was the most prevalent kind; its prevalence was higher in men (57.1%). Witha rate of incidence of 24%, type "g" was the second most prevalent kind; its prevalence was higher in men (66.7%). There were six modifications in the posterior circle. With a prevalence of 26%, the most prevalent variation was c lassic type " a," which was more common in men (61. 5%). 62% of posterior circle types were " d, e, h," which were defined by hypoplasia or absence of PCo A.

However, Ustabaşıoğlu FE et al[25] found that in 82% of instances, the anterior region of CoW had a full structure. In 22.2% of cases, the posterior part's vascular anatomy was complete. They stated that the most common form of variation was bilateral PCoA absence, and that posterior segment changes are more common in CoW examination with magnetic resonance angiography.

Ravikanth R et al[26] examined the patterns and prevalence of arterial variationsin Co W observed in TOF-MRA in a group of CVA subjects. The anterior variant Type A and the posterior variant Type E of CW were the most prevalent in a single subject. The typical adult pattern in the anterior circulation is type A. One ACoA is present. The middle cerebral artery and the precommunicating section of ACA split off from the ICA. Hypoplasia, or the lack of both PCoA and segregation of both the anterior and posterior portion of CoW at this level, characterises type E of posterior circulation. In general, women had slightly higher rates of CoW variants than males did. They asserted that there may be wide variations in the CoW configuration in people of all ages.

In consistent with this study, Sharma R et al [27] reported that only 46.6% of cases had a morphologically regular COW configuration, while 53.4% of cases had a variant configuration. The PCOM variant was found to be the most prevalent, occurring in 67% of instances. The absence of right PCOM was the most frequent variance in the aberrant COW setup.

Đevukaj et al [28] noted that complete CoW was detected in 48. 4% of cases in Serbia, with 68% of cases being female. In 38.1% and 13.6% of individuals, respectively, partially complete and imperfect Co W were found; these subjectswere primarily female. A1 ACA hypoplasia (9.3%) was the most prevalent anterior circulation alteration observed in 27.4% of subjects, with a higher incidence in females (63.8%). 46.4% of subjects had abnormalities in posterior circulation, with hypoplasia (25.6%) and PCo A being the most common causes. 26.2% of individuals had combined alterations, with females having a higher incidence (73.3%). It was remarkable that there were differences in posterior vasculature between female and male subjects, with a larger prevalence in the former group.

Kızılgöz V et al [29] observed that in anterior circulation (75.8%) and posterior circulation (54%), Type A was fithe most prevalent variant. In the anterior circulation, types G and H were the other prevalent variant, while in the posterior COW, types E and D were the next most common variations, respectively. Females were found to have smaller calibrations for both ICAs, P 1s, and BA when compared to the male group. In individuals who had a complete circle, the left PCoA diameter was substantially greater and the BA and both P1 segments had smaller diameters. Addressing the order of appearance of entire, partially complete and imperfect circular groups, there was a substantial difference by age and sex.

However, Enyedi M et al[30] stated that 31% of Romanian population had a classical configuration of Co W. The unilateral lack of a PCo A was the most frequent variation in the posterior circle, whereas the unilateral lack of an ACA's precommunicating segment was the most frequent variation in the anterior circle. In 63 cases, the entire Co W was identified; in 108 and 73 occurrences, respectively, both the posterior and anterior portions produced complete structures. There were eight occurrences with incomplete configurations. In 14 cases, a unilateral foetal PCoA was found and in 6 cases, a bilateral one.

Conclusion:

We infer that the variations in CoW are common in both anterior and posterior circles and the vessel diameter in few selected vessels differ with age, gender and type of

completeness of CoW. Hence, large scale studies are warranted in order to figure out the proportion of subjects with varying morphological CoW.

Funding: Nil

Conflict of interest: Nil

References:

1. Eastcott HHG. The beginning of stroke prevention by surgery. Cardiovasc Surg 1994;2:164 –9.
2. Alnæs MS, Isaksen J, Mardal KA, et al. Computation of hemodynamics in the circle of Willis. Stroke 2007; 38:2500 –5.
3. 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 .
4. 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.
5. Miralles M, Dolz JL, Cotillas J, Aldoma J, Santiso MA, Gimenez A, Capdevila A, Cairols MA. The role of circle of Willis in carotid occlusion: assessment with phase contrast MRA and transcranial duplex. Eur J Vasc Endovasc Surg 1995; 10: 424 –30 .
6. Schomer DF, Marks MP, Steinberg GK, Johnstone IM, Boothroyd DB, Ross MR, Pelc NJ, Enzmann DR. The anatomyof posterior communicating artery as a risk factor for ischemic cerebral infarction. N Engl J Med 1994;330:1565 –70.
7. Hillen B. The variability of circle of Willis: univariate and bivariate analysis. Acta Morphol Neth Scand 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. Macchi C, Catini C, Federico C, Gulisano M, Pacini P, Cecchi F, Corcos L, Brizzi E. Magnetic resonance angiographic evaluation of circulus arteriosus cerebri (circle of Willis): a morphologic study in 100 human healthy subjects. Ital J Anat Embryol 1996;101: 115–23.
10. Barboriak DP, Provenzale JM. Pictorial review: magnetic resonance angiography of arterial variants at the circle of Willis. Clin Radiol 1997;52:429 –36.
11. Rutgers DR, Klijn CJM, Kappelle LJ, et al. Recurrent stroke in subjects with symptomatic carotid artery occlusion is associated

with high- volume flow to the brain and increased collateral circulation. Stroke 2004;35:1345 –9.

12. Van den Boom R, Lesnik Oberstein SA, Spilt A, et al. Cerebral hemodynamics and white matter hyperintensities in CADASIL. J Cereb Blood Flow Metab 2003;23:599 –604.
13. Kato T, Indo T, Yoshida E, et al. Contrast -enhanced 2D cine phase MRA for measurement of basilar artery blood flow in posterior circulation ischemia. AJNR Am J Neuroradiol 2002; 23: 1346 – 51.
14. Rutgers DR, Blankensteijn JD, Van der Grond J. Preoperative MRA flow quantification in CEA subjects: flow differences between subjects who develop cerebral ischemia and subjects who do not develop cerebral ischemia during cross -clamping of carotid artery. Stroke 2000;31: 3021 –8.
15. Cromton MR. The pathology of ruptured middle cerebral aneurisms with special reference to the difference between the sexes. Lancet. 1962; 2;421 -25.
16. Hillen B.The variability of circulus arteriosus (Willisi); Orderor anarchy. Acta Anat (Basel). 1987; 129: 74-80
17. Cavestro C, Richetta L, L'episcopo MR, Pedemonte E, Duca S, Di Pietrantonj C. Anatomical variants of circle of Willis and brain lesions in migraineurs. Canadian journal of neurological sciences. 2011 May; 38(3): 494 -9.
18. Saikia B, Handique A, Phukan P, Lynser D, Jamil M. Study of anomalies in the circle of Willis using magnetic resonance angiography in north eastern India. Journal of Anatomical Society of India. 2014 Jun 1;63(1):67 -73.
19. Qiu C, Zhang Y, Xue C, Jiang S, Zhang W. MRA study on variation of circle of Willis in healthy Chinese male adults. BioMed research international. 2015 Jan 5;2015.
20. Kondori BJ, Azemati F, Dadseresht S. Magnetic resonance angiographic study of anatomic variations of circle of Willis in a population in Tehran. Archives of Iranian medicine. 2017 Apr 1;20 (4)
21. Yeniçeri IÖ, Çullu N, Deveer M, Yeniçeri EN. Circle of Willis variations and artery diameter measurements in the Turkish population. Folia Morphologica. 2017;76(3):420 -5.
22. Shaikh R, Sohail S. MRA-based evaluation of anatomical variation of circle of Willis in adult Pakistanis. JPMA. The Journal of Pakistan Medical Association. 2018;68(2): 187.
23. Shatri J, Cerkezi S, Ademi V, Reci V, Bexheti S. Anatomical variations and dimensions of arteries in the anterior part of circle of Willis. Folia Morphologica. 2019;78(2):259 -66.

24. Zaki SM, Shaaban MH, Abd Al Galeel WA, El Husseiny AA. Configuration of circle of Willis and its two parts among Egyptian: a magnetic resonance angiographic study. Folia Morphologica. 2019; 78(4): 703 -9.
25. Ustabaşıoğlu FE, Solak S. Magnetic resonance angiographic evaluation of anatomic variations of circle of willis. The Medical Journal Of Haydarpaşa Numune Training and Research Hospital. 2019;59 (3):291 -5.
26. Ravikanth R, Philip B. Magnetic resonance angiography determined variations in the circle of Willis: Analysis of a large series from a single center. Tzu -Chi Medical Journal. 2019 Jan; 31(1):52.
27. Sharma R, Pokharel S, Neupane P, Subedi R. Morphological Variation of Circle of Willis in Nepali Population: A 3D Time - of-Flight Magnetic Resonance Angiography Based Study. Journal of Lumbini Medical College. 2021 Jun 30;9(1):5 -pages.
28. Đevukaj M, Nosek I, Vuković M, Kozić D. Variations of circle of willis determined via magnetic resonance angiography: A single-center analysis of serbian population. Journal of Anatomical Society of India. 2022 Jul 1;71(3).
29. Kızılgöz V, Kantarcı M, Kahraman Ş. Evaluation of Circle of Willis variants using magnetic resonance angiography. Scientific Reports. 2022 Oct 20;12(1): 17611.
30. Enyedi M, Scheau C, Baz RO, Didilescu AC. Circle of Willis: anatomical variations of configuration. A magnetic resonance angiography study. Folia morphologica. 2023;82(1):24 -9.