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PREVALENCE OF NORMAL ANATOMICAL VARIATION IN CIRCLE OF WILLIS AMONG PATIENTS UNDERGOING MAGNETIC RESONANCE ANGIOGRAPHY IN SHIFA INTERNATIONAL HOSPITAL

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Abstract

Objectives: *To determine the prevalence and pattern of normal anatomical variations of the Circle of Willis in adult patients undergoing magnetic resonance angiography (MRA) at Shifa International Hospital.* ***Methodology****: The study planned at Department of Radiology, Shifa International Hospital, Islamabad during the period of six months following ethical approval* (June-Nov, 2023). *This cross-sectional study was conducted on 235 patients aged 18–80 years undergoing MRA for various indications. Exclusion criteria included vascular malformations, tumors, diabetes, hypertension, and cerebrovascular events. MRA was performed using a 1.5 Tesla MRI scanner with 3D time-of-flight technique. Anatomical configurations were documented and analyzed using SPSS v20.0.*

Results: *The most common COW variant was Type D (14.9%), followed by Type H (14.0%), B (13.2%), and A (12.3%). Complete circle configurations were uncommon. Variants were more frequent in posterior circulation. No statistically significant association was found between variant type and age (p=0.305) or gender (p=0.833), though variant P was more common in females and older individuals.*

Conclusion: *Anatomical variations in the Circle of Willis are common in the local population, with posterior segment variations predominating. Knowledge of these patterns is essential for neurovascular planning and risk assessment.*

INTRODUCTION

The Circle of Willis-COW is the collateral system that protects the brain from ischemia damage when intracranial arteries become occluded.[1] Circle of willis is an arterial anastomotic ring in the basal cistern of the brain that connects the internal carotid to the vertebrobasilar system.[2] There are anterior and posterior portions. The anterior segment consists of the anterior communicating artery and the A1 segment of the anterior cerebral artery. The posterior section consists of the posterior communicating artery and the P1 segment of the posterior cerebral artery.[3] The anterior communicating artery connects the right and left anterior cerebral arteries, whereas the posterior communicating artery connects the two posterior cerebral arteries to the internal carotid arteries.[4]

There is substantial heterogeneity in the anatomy of circle of willis amongst populations, which reflects the clinical manifestation of the condition. Radiologists, neurosurgeons, and neurologists must be knowledgeable of the normal anatomy and variations of the circle of willis.[5] Magnetic resonance angiography is a noninvasive and radiation-free method for evaluating circle of willis.

According to research conducted on 200 patients, the most prevalent types of circle of willis were the anterior variant TYPE A and the posterior variant TYPE E. TYPE A is the usual adult anterior circulation pattern. A single anterior connecting artery is present. The ICA branches out into the precommunicating portion of the anterior cerebral artery and the middle cerebral artery. In TYPE E, the posterior connecting arteries are hypoplastic or absent, and the anterior and posterior halves of the circle are isolated. The typical variance in circle of willis is more prevalent in females compared to males.[2]

According to a second study done between January 2013 and March 2014 on 503 individuals referred for MRI brain scans, 31.6% exhibited entire structure of circle. The anterior form with the highest frequency is Type A with a prevalence of 52.9%, while in the posterior K variant has frequency of 32.9% being most common and G in among anterior 5.8% with P variant in posterior forms 8.7% were less common variants(B = 10.1%; D = 8.9%; E = 9.9% H = 12.7%; N = 16.1%; O = 31.6%).[6]

According to another study conducted on 665 patients at the Center for imaging Diagnostics, Oncology Institute of Voivodina in 2018 and 2019 showed complete circle of willis was present in 48.42% of the patients, partially complete and incomplete circle of willis in 38.05 and 13.55 % of the cases. Variations in anterior circulation noted in 27.41, among them most common was A1 anterior cerebral artery hypoplasia which was in 9.32% of the cases. Variations in posterior circulation noted in 46.36% of cases, among them most common was posterior communicating artery hypoplasia which was noted in 25.56%. Collective variations noted in 26.24% of the patients.[7] The study conducted on 513 adults at the University Clinical Center, Clinic of Radiology showed agenesis or hypoplasiain in 5.65% of adults, fused anterior cerebral arteries on a short distance in 6.5% and fusion of anterior cerebral artery after a long distance in about 2.5% and median anterior cerebral artery in 2.1% of cases. Normal anterior communicating artery in 68.2%, hypoplasia or absent in 15.66% of cases noted. Double normal anterior communicating artery in 0.6% and fenestrated in 3.89% of the cases was seen.[8]

The rationale of this study is that no local data is available regarding the percentage of various normal variants of COW among the local population. As there exist great variability of the anatomy of the COW in asymptomatic person. Knowledge of these variations among our local population would help in planning surgical procedures as well as preventing unwanted interventions.

METHODOLOGY:

This cross-sectional study was conducted at the Department of Radiology, Shifa International Hospital, Islamabad, over a period of six months following ethical approval of the research synopsis (June-Nov, 2023). The study aimed to assess the frequency and distribution of anatomical variants of the Circle of Willis (COW) in the Pakistani population using magnetic resonance angiography (MRA). A total of 235 patients were included in the study based on a sample size calculated using WHO software for a single group population proportion. The expected prevalence of the P variant of the COW was taken as 5.8%, with a confidence level of 95% and an absolute precision of 3%.

Non-probability consecutive sampling was used for patient selection. Inclusion criteria comprised all male and female patients aged 18 to 80 years who were undergoing MRA for any indication, either through the outpatient or inpatient departments. Exclusion criteria included patients with claustrophobia, known intracranial vascular malformations such as arteriovenous malformations (AVMs), AV fistula, aneurysms, primary intracranial tumors, peripheral vascular disease, diabetes mellitus, hypertension, and

those with MRI findings suggestive of ischemic or hemorrhagic infarction.

All participants underwent an initial MRI brain scan, including diffusion-weighted imaging (DWI), to rule out ischemic or hemorrhagic stroke before proceeding with MRA. The MRA was performed using a 1.5 Tesla MR scanner (Vantage Titan, Toshiba) employing a 3D time-of-flight (TOF) sequence with spoiled gradient echo technique to obtain high-resolution angiographic images. These images were reviewed independently by a consultant radiologist who was blinded to clinical details to ensure unbiased reporting. Anatomical variants of the Circle of Willis were documented using a structured proforma.

Information on patients' age, gender, and Circle of Willis configurations was collected and analyzed using SPSS version 20.0. Age was analyzed as a quantitative variable using mean and standard deviation, while gender and anatomical variants were presented as frequencies and percentages. To evaluate potential confounding, data were stratified by age and gender. A Chi-square test was used post-stratification, and significance was determined at $p<0.05$.

RESULTS:

A total of 235 adult patients, aged 18 to 80 years, were included in the study and evaluated via magnetic resonance angiography for Circle of Willis anatomy. The mean age was 47.09 years with a standard deviation of 14.52 years, indicating a diverse adult cohort.

Participants were divided into two age groups for analysis. The majority of the individuals (60.0%, n = 141) were between 18 and 50 years of age, while the remaining 40.0% (n = 94) fell into the older age group of 51 to 80 years. This stratification reflects a balanced inclusion of both younger and older adults, enhancing the generalizability of the findings across a wide adult age range. In terms of gender distribution, female participants comprised a slightly higher proportion of the sample. There were 124 females (52.8%) and 111 males (47.2%). This near-equal gender representation ensures that the results are reflective of both sexes and allows for reliable comparisons when analyzing the anatomical variations of the Circle of Willis.(Table 1)

Table 1: Demographic Characteristics of the Study Participants (n = 235)

Variable	Category	Frequency (n)	Percent (%)
Age Group (years)	18–50	141	60.0
	51–80	94	40.0
Gender	Male	111	47.2
	Female	124	52.8

Table 2 displays the frequency distribution of anatomical variants of the Circle of Willis (COW) identified through MRA. The most common variant observed was Type D (14.9%), followed closely by Type H (14.0%) and Type B (13.2%). Other relatively frequent variants included A (12.3%), C and N (each 9.4%), and O (9.4%). Less common variants included E (6.8%), P (6.4%), and K (4.7%). These findings are illustrated in Figure 1, a pie chart that visually represents the proportional distribution of each COW variant across the study cohort.

Table 2: Frequency Distribution of Circle of Willis Variants (n = 235)

COW Variant	Frequency (n)	Percent (%)	Cumulative Percent (%)
A	29	12.3	12.3
B	31	13.2	25.5
C	21	8.9	34.5
D	35	14.9	49.4

E	16	6.8	56.2
H	33	14.0	70.2
K	11	4.7	74.9
N	22	9.4	84.3
O	22	9.4	93.6
P	15	6.4	100.0

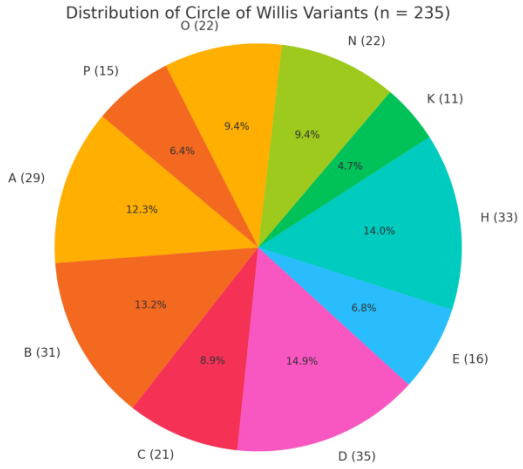

Fig. 1

Table 3 provides a stratified analysis of COW variants by age group. Although variant D remained the most common across both age groups, some differences in distribution were noted. For instance, variant P was more frequently observed in the older age group (11.7%) compared to the younger group (2.8%). Conversely, variant A showed a slightly higher prevalence in younger patients (12.8%) than older patients (11.7%). However, the differences in distribution of variants between the two age groups were not statistically significant, as indicated by a Pearson chi-square p-value of 0.305.

Table 3: Stratified Frequency of Circle of Willis Variants by Age Group

COW Variant	Age(years)		Total n (%)	P value
	18–50 n (%)	51–80 n (%)		
A	18 (12.8%)	11 (11.7%)	29 (12.3%)	0.305
B	21 (14.9%)	10 (10.6%)	31 (13.2%)	
C	15 (10.6%)	6 (6.4%)	21 (8.9%)	
D	23 (16.3%)	12 (12.8%)	35 (14.9%)	
E	8 (5.7%)	8 (8.5%)	16 (6.8%)	
H	19 (13.5%)	14 (14.9%)	33 (14.0%)	
K	7 (5.0%)	4 (4.3%)	11 (4.7%)	
N	12 (8.5%)	10 (10.6%)	22 (9.4%)	
O	14 (9.9%)	8 (8.5%)	22 (9.4%)	
P	4 (2.8%)	11 (11.7%)	15 (6.4%)	

Table 4 outlines the distribution of COW variants stratified by gender. Both male and female participants demonstrated a similar distribution pattern for most variants. For example, variant D was found in 15.3% of males and 14.5% of females, while variant H occurred in 14.4% and 13.7% of males and females, respectively. Notably, variant P was more frequent in females (8.9%) compared to males (3.6%). Despite these variations, the differences in COW variant distribution between genders were also statistically non-significant, with a p-value of 0.833.

Table 4: Stratified Frequency of Circle of Willis Variants by Gender Group

COW Variant	Male n (%)	Female n (%)	Total n (%)	P value
A	13 (11.7%)	16 (12.9%)	29 (12.3%)	0.833
B	16 (14.4%)	15 (12.1%)	31 (13.2%)	
C	10 (9.0%)	11 (8.9%)	21 (8.9%)	
D	17 (15.3%)	18 (14.5%)	35 (14.9%)	
E	10 (9.0%)	6 (4.8%)	16 (6.8%)	
H	16 (14.4%)	17 (13.7%)	33 (14.0%)	
K	4 (3.6%)	7 (5.6%)	11 (4.7%)	
N	10 (9.0%)	12 (9.7%)	22 (9.4%)	
O	11 (9.9%)	11 (8.9%)	22 (9.4%)	
P	4 (3.6%)	11 (8.9%)	15 (6.4%)	

DISCUSSION:

This study assessed the prevalence and distribution of anatomical variants of the Circle of Willis (COW) in 235 adult patients undergoing magnetic resonance angiography (MRA) at Shifa International Hospital. The most common variant identified was Type D (14.9%), followed by Type H (14.0%) and Type B (13.2%). Complete circles were relatively uncommon, consistent with the findings of previous literature. In our cohort, only a small proportion demonstrated complete anatomical configuration of the COW, which is in agreement with a local study by Maryam et al., where only 11.5% of patients had a complete circle, and Type D was also the most prevalent variant.[9] Similarly, Kumari et al. observed that only 33% of their study population had a complete Circle of Willis using CTA, with 67% displaying one or more anatomical variations, particularly in the posterior segment.[10] This trend of high variability supports the hypothesis that complete COW configurations are relatively rare in the general population.

Regarding gender, our study found no statistically significant differences in the distribution of variants (p = 0.833), though variant P was slightly more frequent in females (8.9%) than males (3.6%). These results are consistent with findings from Hashem et al., who noted that partially complete COWs were most prevalent in both sexes, with no significant gender-based anatomical difference.[11] Greggio et al. also explored developmental influences, noting that preterm birth leads to more hypoplastic or accessory vessels, but this did not translate into clear gender differences.[12]

Age-related differences were also not statistically significant in our study (p = 0.305), although we observed that variant P was more common in older participants. These findings echo those of Amjad et al[13] who reported that anterior circle variations, especially involving the A1 segment of the anterior cerebral artery, were more frequent in aging populations, potentially due to physiological vascular remodeling.

Posterior circulation variations were more prevalent in our cohort compared to anterior variants, consistent with multiple prior reports. Brohi et al[14] found posterior COW variations in 38.3% of their patients, with unilateral hypoplastic posterior communicating artery

(PComA) being the most common. Similarly, Haghighimorad et al[15] demonstrated that PComA hypoplasia/aplasia was present in 77.5% of patients and significantly associated with thalamic infarcts, highlighting the clinical implications of these anatomical differences. An important aspect highlighted by our findings is the need for radiologists and neurosurgeons to be aware of these variations when planning interventions or interpreting neuroimaging. Gunasekaran et al. emphasized the significance of fetal-type posterior cerebral arteries (FPCAs), found in 20–30% of cases, which can impact cerebral hemodynamics and stroke risk.[16] In our sample, variant P (potentially related to FPCA pattern) was seen in 6.4%, and more often in older females, which aligns with their results.

Furthermore, Ella et al[17] used CTA and reported incomplete COW in 51.3% of their sample, with anterior and posterior variations being more frequent in females. Although our findings did not reach statistical significance, the trend was similarly observed and supports the growing body of literature on gender-related vascular patterns. The significance of identifying these variants is underscored by the functional consequences they may pose. Zehra et al[18] and Khandaker et al[19] linked vascular anomalies post-stroke with neuropsychiatric symptoms and cognitive impairment. Our exclusion criteria ruled out ischemic or hemorrhagic lesions; however, the anatomical variation data can still help anticipate cerebrovascular risk in asymptomatic individuals.

Finally, the relatively high prevalence of COW variations in our study is in line with multiple studies across South Asia and the Middle East, including those from Nepal[9] and Saudi Arabia,[11] emphasizing that COW anatomical variability is a universal rather than population-specific phenomenon. This affirms the importance of incorporating routine MRA in risk assessment and treatment planning, especially in patients with suspected cerebrovascular anomalies.

CONCLUSION

This study highlights the significant prevalence of anatomical variations in the Circle of Willis among the local Pakistani population, with Type D being the most frequently observed configuration. Although gender and age-related differences in variant distribution were not statistically significant, patterns such as higher frequency of variant P in females and older individuals suggest possible demographic influences. Our findings are consistent with regional and international studies that report similar patterns, particularly involving the posterior circulation. Understanding these variations is essential for clinicians involved in neuroimaging, neurosurgery, and stroke management, as they have critical implications for cerebral perfusion and vascular risk. Routine evaluation of Circle of Willis anatomy using non-invasive MRA can aid in early recognition of cerebrovascular vulnerabilities, guide surgical planning, and improve outcomes.

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