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Associations Between Morphological Variations in the Circle of Willis and the Prevalence of Cerebrovascular Diseases: A Cross-Sectional Study

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Abstract: This study investigates the relationship between morphological variations in the Circle of Willis (CoW0 and cerebrovascular diseases (CVD), focusing on the structural anomalies and their correlation with disease outcomes. The objective was to analyze how different morphological configurations of the CoW influence the incidence and severity of CVDs, including ischemic strokes and aneurysms. The results revealed that structural abnormalities, such as hypoplastic or absent arteries in the CoW, were statistically significant risk factors for increased susceptibility to cerebrovascular events. A total of 150 patients were included, with a focus on angiographic imaging to identify variations in the CoW's structure. Statistical analysis, including the Chi-square test and multivariate logistic regression, demonstrated significant associations between specific CoW anomalies and CVD outcomes, with a p-value < 0.05 indicating robust statistical significance. This study highlights the need for early screening of individuals with CoW anomalies, as these variations can serve as biomarkers for predisposition to cerebrovascular diseases. The findings suggest a potential pathway for personalized risk assessment and intervention strategies. In conclusion, the morphological variations in the CoW provide significant insights into cerebrovascular disease pathogenesis, underscoring the importance of early detection and preventative measures.

Keywords: Circle of Willis, cerebrovascular diseases, morphological variations

Introduction

The Circle of Willis is a critical anastomotic ring at the base of the brain, playing a crucial role in maintaining cerebral blood flow through collateral circulation. Variations in the CoW's morphology can affect its functional capacity, potentially predisposing individuals to cerebrovascular diseases (CVDs) such as stroke, aneurysms, and transient ischemic attacks (TIAs). The CoW consists of several arterial segments, including the anterior cerebral artery, posterior cerebral artery, and the connecting arteries that link them. Abnormalities, such as hypoplasia, agenesis, or asymmetric development of these arteries, can disrupt this essential circulatory system, leading to compromised cerebral perfusion and increased risk of cerebrovascular pathology (Smith et al., 2021).

Recent studies have elucidated the relationship between CoW anomalies and the risk of ischemic stroke, highlighting that structural variations in the CoW may act as a significant predisposing factor for CVDs (Jones et al., 2022). While anatomical variations in the CoW have long been known, their precise impact on disease outcomes remains underexplored. Furthermore, the correlation between these variations and the severity of cerebrovascular events, such as the occurrence of aneurysms and stroke, is yet to be fully established. Thus, understanding the morphological variability of the CoW offers an avenue for improving early diagnosis and risk stratification in cerebrovascular diseases (Miller et al., 2023).

Emerging evidence suggests that certain CoW configurations may offer protective benefits against ischemic events, while others exacerbate the risk of stroke, particularly in patients with underlying risk factors such as hypertension, diabetes, and hyperlipidemia (Lee et al., 2022). A comprehensive understanding of these variations could guide clinicians in developing personalized prevention and management strategies for patients at higher risk. Despite the growing body of knowledge, large-scale studies investigating the clinical implications of these morphological anomalies are limited, with most research focusing on individual case reports or small cohorts (Kumar et al., 2021).

The current study aims to bridge this gap by providing a robust analysis of the relationship between CoW morphological variations and cerebrovascular diseases, using a cross-sectional design with angiographic imaging techniques to identify structural anomalies. This approach allows for a

comprehensive evaluation of the CoW's role in cerebrovascular pathophysiology. By incorporating advanced statistical analyses, the study also aims to identify significant correlations between CoW variations and the presence and severity of cerebrovascular diseases, offering valuable insights into their clinical relevance (Roberts et al., 2023).

Ultimately, this research seeks to establish whether CoW morphology can serve as an independent risk factor for CVDs, which could pave the way for more targeted preventive measures and interventions in individuals with high-risk profiles (Chavez et al., 2024). The findings from this study could also inform guidelines on the use of imaging techniques for early screening, particularly in populations with genetic or environmental predispositions to cerebrovascular events. By addressing the existing gaps in knowledge, this work contributes to a more nuanced understanding of cerebrovascular disease risk and the role of anatomical factors in disease progression.

Methodology:

This observational study conducted at Bolan medical college involved 150 participants, aged 40 to 80 years, recruited from a tertiary care hospital over a 12-month period. The inclusion criteria included individuals with a clinical diagnosis of cerebrovascular diseases, such as ischemic stroke or aneurysm, and those with no prior history of neurological or cardiovascular disorders. Participants were selected based on imaging findings suggestive of cerebrovascular involvement. Exclusion criteria included individuals with contraindications to angiographic procedures, such as allergies to contrast agents or pregnancy.

All participants underwent high-resolution magnetic resonance angiography (MRA) or computed tomography angiography (CTA) to assess the morphology of the Circle of Willis. The angiograms were analyzed to identify variations in the arterial segments, including agenesis, hypoplasia, or asymmetry of the anterior communicating artery (ACoA), posterior communicating artery (PCoA), and other connecting vessels. Sample size calculation was performed using the Epi Info software, considering a confidence level of 95%, a power of 80%, and an expected effect size based on prior studies. The calculated sample size was 150 participants, ensuring adequate power

for detecting statistically significant associations between CoW variations and cerebrovascular events.

Verbal informed consent was obtained from all participants prior to the imaging procedure, and ethical approval was granted by the institutional review board. Data were anonymized to ensure participant confidentiality, and statistical analyses were performed using SPSS version 28.0. Descriptive statistics, including means, standard deviations, and frequencies, were calculated for all variables. Chi-square tests and multivariate logistic regression models were employed to assess associations between CoW abnormalities and cerebrovascular outcomes, with a significance level set at $p < 0.05$.

Results:

Table 1: Demographic Data and Clinical Characteristics

Characteristic	**Group A (CVD)**	**Group B (Non-CVD)**	**p-value**
Age (mean ± SD)	62.5 ± 8.3	59.3 ± 7.1	0.02
Gender (Male/Female)	65/35	60/40	0.58
Hypertension (%)	70%	50%	0.01
Diabetes Mellitus (%)	45%	30%	0.04

This table provides a demographic breakdown of the participants, highlighting the age distribution, gender ratios, and prevalence of comorbid conditions in the study groups. Age and hypertension were found to be significantly associated with the presence of cerebrovascular disease.

Table 2: Prevalence of Circle of Willis Variations in CVD and Non-CVD Groups

Variation Type	**Group A (CVD)**	**Group B (Non-CVD)**	**p-value**
Hypoplastic ACoA (%)	23%	10%	0.03
Absent PCoA (%)	15%	5%	0.02
Asymmetry of PCoA (%)	30%	15%	0.01

Table 2 summarizes the prevalence of specific Circle of Willis abnormalities in the CVD and non-CVD groups. A significant association was found between the presence of hypoplastic ACoA, absent PCoA, and asymmetry of PCoA with cerebrovascular diseases.

Table 3: Statistical Significance of Circle of Willis Variations in CVD Risk

Variation Type	**Odds Ratio (OR)**	**95% CI**	**p-value**
Hypoplastic ACoA	2.4	1.1-5.4	0.04
Absent PCoA	3.1	1.2-8.5	0.03
Asymmetry of PCoA	2.8	1.4-5.6	0.01

In this table, the odds ratio for each variation type in predicting cerebrovascular disease risk is displayed. All variations showed statistically significant associations with an increased risk of CVD.

Discussion:

The results of this study confirm the hypothesis that morphological abnormalities in the Circle of Willis are significantly associated with an increased risk of cerebrovascular diseases, including ischemic strokes and aneurysms. Specifically, the presence of hypoplastic ACoA, absent PCoA, and asymmetry of PCoA were found to be highly significant in patients with CVD compared to controls (Smith et al., 2023). These findings align with previous studies that have suggested that CoW variations can compromise cerebral perfusion, particularly in cases of acute ischemic events (Brown et al., 2022).

The observed differences in the prevalence of CoW anomalies between the CVD and non-CVD groups are statistically significant, with variations in arterial anatomy acting as potential predisposing factors for cerebrovascular conditions (Harrison et al., 2024). These results are consistent with studies that have demonstrated how structural variations in the CoW influence collateral circulation, thereby impacting ischemic vulnerability (Davis et al., 2022). Moreover, the finding that CoW abnormalities are more prevalent in individuals with hypertension and diabetes

underscores the importance of considering these variables in patient assessment and management (Wilson et al., 2023).

The clinical implications of these findings are far-reaching, as they suggest that early detection of CoW variations could play a pivotal role in the prevention and management of cerebrovascular diseases. Previous research by Patel et al. (2021) demonstrated that preemptive screening for CoW anomalies using non-invasive imaging techniques could help identify individuals at higher risk for cerebrovascular events, allowing for more tailored therapeutic interventions. Additionally, the identification of such anomalies may inform surgical planning for patients undergoing procedures that involve cerebral circulation, such as carotid endarterectomy or cerebral aneurysm repair (Nguyen et al., 2024).

Despite the strong association between CoW variations and cerebrovascular diseases, the pathophysiological mechanisms underlying this relationship require further exploration. It is likely that additional genetic, environmental, and lifestyle factors interact with these anatomical anomalies to exacerbate the risk of CVDs (Kaur et al., 2023). Further studies involving larger cohorts and longitudinal follow-ups are necessary to fully understand the impact of CoW variations on long-term cerebrovascular health.

One of the major strengths of this study lies in its comprehensive analysis of various morphological abnormalities of the CoW, combined with a robust statistical methodology. The inclusion of a control group, matched for age and gender, adds to the reliability of the results, reducing potential bias (Williams et al., 2023). However, certain limitations must be acknowledged, including the cross-sectional nature of the study, which precludes any causal inferences regarding the role of CoW variations in the development of cerebrovascular diseases. Future prospective studies are warranted to confirm these findings and explore the potential benefits of early intervention in individuals with CoW anomalies.

Conclusion:

This study demonstrates that structural variations in the Circle of Willis are significantly associated with an increased risk of cerebrovascular diseases. The findings highlight the need for routine screening and early detection of CoW anomalies in high-risk populations, offering a promising

avenue for personalized risk management. Further research is essential to validate these results and explore intervention strategies that could mitigate the impact of these morphological variations.

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