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A Systematic Review

Comparative Evaluation of Variations in Cerebral Arterial Circulation on Imaging in Stroke and Non-Stroke Patients

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Abstract:

Introduction: This study investigates the variations in cerebral arterial circulation, particularly within the Circle of Willis (CoW), and their association with stroke occurrence. The CoW is an essential arterial network at the base of the brain that facilitates collateral blood flow during arterial blockage. Anatomical variations in this structure, such as hypoplastic or absent arteries, are believed to influence stroke risk.

Methods: The study analyzed CoW configurations in a sample of 1,209 stroke and non-stroke patients using non-invasive 3D time-of-flight magnetic resonance angiography (MRA). Patients were categorized based on the presence or absence of ischemic or hemorrhagic stroke as observed on MRA.

Results: Significant associations were found between an incomplete CoW configuration and the presence of stroke. Specific variations, including hypoplastic middle cerebral artery (MCA) and A1 segments, were notably more prevalent among stroke patients, suggesting a link with increased stroke risk. In contrast, the fetal posterior cerebral artery (PCA) variation was more common in non-stroke patients, potentially indicating a less harmful role.

Conclusion: The findings highlight the importance of evaluating CoW variations for stroke risk assessment. The use of 3D-TOF MRA provides a valuable non-invasive approach for identifying high-risk individuals. This study contributes critical insights for early identification and improved management strategies for individuals with elevated stroke susceptibility.

Keywords: Circle of Willis, stroke, magnetic resonance angiography, cerebral arterial variations

Introduction

The topic of cerebral arterial circulation variations in stroke and non-stroke patients centers on the anatomical differences within the Circle of Willis (CoW) and their potential impact on cerebrovascular health [1]. The Circle of Willis, an arterial structure at the brain's base, is critical for maintaining collateral blood flow, especially in cases of arterial blockage or compromised blood flow. Variations in this arterial structure, such as hypoplastic or absent arteries, can influence the risk and manifestation of ischemic or hemorrhagic strokes [2,3].

This study examines these anatomical variations using non-invasive magnetic resonance angiography (MRA), specifically 3D time-of-flight (TOF) imaging, in both stroke and non-stroke patients [4,5]. By comparing the presence and types of CoW variations between these groups, the study seeks to determine any significant association between specific variations and the occurrence of stroke. Such insights could have implications for the early identification of high-risk individuals and inform treatment strategies in neurology and vascular surgery [6,7].

To evaluate variations in cerebral arterial circulation on MRA in stroke and non-stroke patients and analyze their association with the incidence of stroke.

Methodology

Study Design

This was a cross-sectional observational study conducted to evaluate variations in cerebral arterial circulation on magnetic resonance angiography (MRA) in stroke and non-stroke patients.

Study Location

The study was carried out in the Department of Radiodiagnosis and Imaging at Sikkim Manipal Institute of Medical Sciences, Sikkim, Gangtok.

Study Duration

The study period spanned two years, from October 2017 to September 2019.

Sample Size

A total of 1,209 patients referred for brain MRI were included. This time-bound study enrolled all eligible patients who met the inclusion and exclusion criteria during the study period.

Study Population

Patients of all age groups and both genders referred for MRI brain imaging due to neurological symptoms were included.

Inclusion Criteria

1. Patients referred for brain MRI who provided informed consent.
2. Patients across all age groups and genders.

Exclusion Criteria

1. Patients who refused to provide consent.
2. Patients with MRI-incompatible implants (such as metallic implants, pacemakers, or surgical staples) or contraindications like claustrophobia.
3. Poor-quality or artifact-distorted images were excluded from the analysis.

Data Collection Procedure

Each patient underwent a 3D time-of-flight (TOF) MRA using a 1.5 Tesla Philips Achieva MRI machine with a 16-channel coil. Both new cases and archived imaging data were included. MRI findings were used to categorize patients into stroke and non-stroke groups based on the presence or absence of ischemic or hemorrhagic stroke as observed on MRI brain imaging.

Data Analysis

MRA findings of the cerebral arterial circulation, especially within the Circle of Willis (CoW), were analyzed to identify and categorize variations. These variations

were then statistically compared between stroke and non-stroke groups. Data was entered into Microsoft Excel and analyzed using SPSS software version 22. Categorical data were represented as frequencies and proportions, and associations between categorical variables were assessed using the Chi-square test, with a p-value < 0.05 considered statistically significant.

Results

In this study, the presence and types of cerebral arterial circulation variations were evaluated in 1,209 patients, categorized into stroke and non-stroke groups. The results reveal significant differences in the configuration of the Circle of Willis (CoW) and variations in arterial structure between these two groups.

Table 1: Stroke Distribution Among Study Subjects

Stroke Status	Count	Percentage (%)
Stroke	266	22.0%
Non-stroke	943	78.0%
Total	1209	100.0%

Out of 1,209 study subjects, 22% (266) presented with a stroke, while 78% (943) did not have a stroke. This distribution provides a baseline for comparing variations in the cerebral arterial circulation between the stroke and non-stroke groups.

Table 2: Association Between Stroke and Circle of Willis (CoW) Configuration

CoW Configuration	Stroke Patients	Non-stroke Patients	Total	p-value
Complete	205 (77.1%)	857 (90.9%)	1062	<0.001*
Incomplete	61 (22.9%)	86 (9.1%)	147	
Total	266	943	1209	

This table shows a significant association between stroke occurrence and the Circle of Willis configuration. Among stroke patients, 22.9% had an incomplete CoW, compared to only 9.1% of non-stroke patients. Conversely, a complete CoW was more common in non-stroke patients (90.9%) than in stroke patients (77.1%), indicating a potential protective role of a complete CoW configuration.

Table 3: Types of CoW Variations Identified in Stroke and Non-Stroke Patients

Type of Variation	Stroke Patients (%)	Non-stroke Patients (%)	Total (%)
Fetal PCA	27.9	40.7	35.4
Hypoplastic A1	18.0	33.7	27.2
Hypoplastic MCA	26.2	1.2	11.6
Other Variations	27.9	24.4	26.5
Total	100.0	100.0	100.0

Fetal PCA and hypoplastic A1 segments were the most common CoW variations in both groups. Among stroke patients, hypoplastic MCA was notably more prevalent (26.2%) than in non-stroke patients (1.2%), suggesting this variation may correlate with increased stroke risk. Conversely, the fetal PCA variation was more common among non-stroke patients (40.7%), indicating it may not be as strongly associated with stroke risk as other variations.

The study found that an incomplete Circle of Willis configuration is significantly more common in stroke patients than in non-stroke patients. Specific variations, such as hypoplastic MCA and hypoplastic A1, are also associated with stroke presence, while the fetal PCA variation was more frequent in non-stroke patients. These findings suggest that certain variations in cerebral arterial anatomy may influence stroke risk, underscoring the importance of evaluating these variations in clinical settings.

Discussion

This study evaluated cerebral arterial variations using 3D-TOF MRA in 1,209 patients, comparing configurations of the Circle of Willis (CoW) in stroke and non-stroke groups. The findings indicate that certain anatomical variations, such as an incomplete CoW and specific variations like hypoplastic middle cerebral artery (MCA), are associated with an increased incidence of stroke. These results align with previous studies while contributing unique insights specific to the regional population.

Our study shows that an incomplete CoW configuration was more frequent among stroke patients (22.9%) than non-stroke patients (9.1%). This finding is consistent with previous studies, such as those by Harizi et al., who found a similar association between CoW variations and stroke risk in their analysis of the Albanian population [8]. Likewise, Al-Hussain et al.'s study on the Jordanian population found that variations in the CoW are common and significantly impact cerebral blood flow, highlighting the importance of these structures in stroke risk assessment [9].

The types of CoW variations observed in this study provide additional insights. The fetal posterior cerebral artery (PCA) was the most common variation overall, more frequently seen in non-stroke patients (40.7%), suggesting it may be less detrimental in terms of stroke risk. Conversely, hypoplastic A1 and MCA segments were more frequently observed in stroke patients, which aligns with findings from studies by Dimmick et al. and Makowicz et al., who also observed a higher incidence of anterior CoW variations in stroke-prone individuals [10,11]. These differences in variation frequencies could reflect the importance of collateral flow capability in the cerebral vasculature, where certain configurations offer better protection against ischemic events.

Future studies should explore the clinical significance of these variations in broader and more diverse populations to validate the findings across ethnic and regional differences. Prospective longitudinal studies are also recommended to assess whether patients with specific CoW variations are at a higher risk for stroke over time [12,13]. Additionally, incorporating morphometric data on cerebral artery diameters could provide more precise correlations between specific anatomical variations and stroke outcomes, allowing for tailored risk assessment and potentially preventative interventions [14].

Furthermore, technological advancements, such as high-resolution MRI and 3T MRA, could enhance the sensitivity and accuracy of vascular imaging, allowing for a deeper understanding of the role of cerebral arterial variations. Including additional parameters like blood flow velocity and direction could further elucidate the impact of these variations on hemodynamics, improving predictive capabilities in clinical settings [15].

Conclusion

This study demonstrates a significant association between an incomplete Circle of Willis and the occurrence of stroke, particularly with variations such as hypoplastic MCA and A1 segments. These variations appear to reduce collateral circulation efficacy, potentially increasing stroke susceptibility. By contrast, the fetal PCA variation, more common in non-stroke patients, may indicate a benign or even protective effect. The findings support the use of 3D-TOF MRA as a valuable non-invasive imaging technique for assessing cerebral arterial variations.

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