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Original Article

A Prospective Study to Find the Relationship of Carotid Stenosis and Plaque Morphology with Infarct Volume in Ischemic Stroke Patients

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Abstract

Background: Ischemic stroke, a major global health concern, is often caused by carotid artery stenosis resulting from atherosclerotic plaque formation. Carotid Doppler ultrasonography is a non-invasive method to assess the degree of stenosis and the characteristics of plaques, which are crucial in evaluating stroke risk and guiding treatment decisions. ***Objective:*** This study aimed to explore the relationship between the percentage of carotid artery stenosis, plaque morphology, and infarct volume in patients with acute ischemic stroke. ***Design:*** Cross-sectional analysis. ***Subjects/Patients:*** Fifty patients diagnosed with ischemic stroke at the Department of Radiodiagnosis, PSG Institute of Medical Sciences and Research, Coimbatore, between January 2019 and June 2020. ***Methods:*** Carotid Doppler ultrasound was used to quantify stenosis and classify plaques based on echogenicity, surface contour, and internal texture. Infarct volumes were measured using MRI. Statistical correlations and regression analyses were conducted to identify significant relationships. ***Results:*** Carotid stenosis was observed bilaterally in half of the cohort, with average stenosis of 62.2% (right) and 55.4% (left). A moderate positive correlation was found between stenosis percentage and infarct volume (r=0.446, p=0.035). Plaque morphology did not significantly correlate with infarct size. Regression analysis showed that age and stenosis severity accounted for 48% of infarct volume variation. ***Conclusion:*** Carotid stenosis severity is a more reliable predictor of infarct volume than plaque morphology, highlighting the value of Doppler-based stenosis assessment in ischemic stroke management.

Keywords: ***Atherosclerosis, Carotid Artery, Carotid Stenosis, Ischemic Stroke, Magnetic Resonance Imaging, Ultrasonography.***

Introduction

Stroke is a critical public health issue globally and is characterized by the World Health Organization as "a clinical syndrome that consists of rapidly developing clinical signs of focal disturbance of cerebral function lasting more than 24 hours" [1]. It remains one of the most significant causes of long-term disability and mortality worldwide [2]. Stroke is broadly categorized into hemorrhagic and ischemic types. Hemorrhagic strokes, resulting from vascular rupture and subsequent bleeding into the brain parenchyma or subarachnoid space, account for approximately 20% of all cases [2]. Conversely, ischemic strokes, which constitute the remaining 80%, typically arise from arterial occlusion or stenosis, with the middle cerebral artery being the most frequently affected.

Hypertension and atherosclerosis of the carotid arteries are well-established risk factors. The pathogenesis of ischemic stroke often involves thromboembolic phenomena, primarily associated with atherosclerotic plaques in the carotid arteries. These high-risk plaques, particularly those with features such as rupture, fissuring, or ulceration, can serve as embolic sources [3]. Plaques implicated in ischemic stroke frequently display characteristics such as a lipid-rich necrotic core (LRNC), intraplaque hemorrhage (IPH), and fibrous cap rupture (FCR) [4].

Imaging modalities like computed tomography (CT), magnetic resonance imaging (MRI), and angiography are crucial for stroke diagnosis. Among these, carotid Doppler ultrasonography is particularly useful for evaluating extracranial carotid artery disease. It is a non-invasive, accessible method that provides valuable information regarding both the degree of stenosis and plaque morphology [5]. This includes early identification of atherosclerotic changes at the carotid bifurcation and classification of plaques by echogenicity, texture, and surface regularity. Several studies have demonstrated that both the severity of stenosis and the morphological characteristics of plaques can be predictive of stroke

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recurrence and infarct burden [5,6]. Notably, plaques with hypoechoic or ulcerated features have been associated with larger infarct volumes and more severe neurological outcomes [7].

The purpose of this study is to explore the relationship between carotid artery stenosis and plaque morphology, as assessed by carotid Doppler ultrasound, and infarct volume measured on MRI in patients with acute ischemic stroke. By evaluating these parameters, the study aims to enhance our understanding of stroke pathophysiology and improve risk stratification and management in clinical practice.

Objectives

1. To determine the relationship between percentage of carotid stenosis and severity of ischemic stroke in terms of infarct volume on MRI.
2. To assess the relationship between carotid plaque morphology and infarct volume.

Methods

Study Design

This study was conducted as a prospective cross-sectional analysis.

Study Setting

The research was carried out in the Department of Radio diagnosis at PSG Institute of Medical Sciences and Research, Coimbatore, Tamil Nadu.

Study Period

Data collection spanned from January 2019 to June 2020.

Study Population

The study included patients presenting for MRI within 24 hours of the onset of symptoms indicative of acute ischemic stroke.

Inclusion Criteria

1. Patients with an acute infarct in areas supplied by the internal carotid artery.
2. Patients whose cerebral Diffusion-Weighted MRI (DWI) quality was sufficient to allow adequate volume measurement within 24 hours of symptom onset.
3. Patients who underwent carotid Doppler subsequent to MRI.

Exclusion Criteria

1. Patients with infarcts in multiple vascular territories.
2. Patients with posterior circulation infarcts.
3. Patients with non-ischemic strokes.
4. Patients who developed hemorrhagic transformation.
5. Patients with normal carotid Doppler results.
6. Patients who underwent MRI after thrombolytic therapy.

Sample Size

The sample size was determined using the formula:

Sample size=$(Z1-\alpha/2)2\times SD2d2$Sample size=$d2(Z1-\alpha/2)2\times SD2$

where:

- $Z1-\alpha/2Z1-\alpha/2$ = standard normal variate for a 95% confidence interval (1.96),
- SD = standard deviation (0.72, based on prior study data)[8],
- dd = precision or absolute error (set at 0.2 mm).

Using these parameters, the sample size was calculated to be 50.

Methodology

MRI Evaluation

MRI brain imaging was performed on all patients within 24 hours of symptom onset using a Siemens Tesla MR Scanner. The MRI protocol included the following sequences:

- T1 Weighted Image: Sagittal plane
- T2 Weighted Image: Axial and sagittal planes, fast spin echo sequence
- T2-FLAIR: Axial plane
- Diffusion Weighted Imaging (DWI): Axial plane with b-values of 0, 500, and 1000, including
- Apparent Diffusion Coefficient (ADC)
- Susceptibility Weighted Imaging (SWI): Axial plane

The DWI hyperintense area with restricted diffusion was manually measured by tracing each slice. The total area was summed and multiplied by slice thickness (plus slice gap) to estimate the infarct volume [9].

Carotid Doppler Evaluation

Following MRI, patients underwent carotid Doppler evaluation with a Siemens Acuson S2000 system using an 18L6 linear transducer. This procedure was conducted with the patient in a supine position with neck extension. Key assessments included:

- Intima Media Thickness: Measured in the common carotid artery in longitudinal section.
- Plaque Characterization: Based on echogenicity, texture, and surface features following the modified Gray-Weale classification [10].
  - Echogenicity:
    - Type 1: Uniformly anechoic/hypoechoic.
    - Type 2: Predominantly hypoechoic (>50%).
    - Type 3: Predominantly hyperechoic (>50%).
    - Type 4: Uniformly hyperechoic.
    - Type 5: Unclassified due to poor visualization or calcifications.
  - Texture: Defined as homogenous (uniform consistency) or heterogenous (non-uniform consistency).
  - Surface: Categorized as smooth/regular or irregular (with variations in plaque contour from 0.4 to 2 mm).
  - Ulcerations: Defined as a recess of at least 2 mm depth and length, with a well-defined wall and flow reversal or low signal at the recess level [11].

Stenosis Measurement

Diameter stenosis was measured transversely using the traditional (University of Washington) method, comparing residual lumen to original luminal diameter. Stenosis degree was classified into four categories: <50%, 50-69%, 70-99%, and complete occlusion [12]. Spectral Doppler analysis was conducted on the common, internal, and external carotid arteries, measuring peak systolic and end-diastolic velocities.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics software (version 21). Descriptive statistics were used to summarize continuous variables (mean, standard deviation, range) and categorical variables (frequency and percentage). The Kruskal-Wallis test was employed to evaluate differences in carotid artery stenosis and infarct volume across groups for continuous data. Spearman's rank-order correlation was utilized to assess relationships between numerical variables. Additionally, multiple linear regression analysis was conducted to identify predictors of infarct volume. A p-value of less than 0.05 was considered indicative of statistical significance. Quantitative assessment of carotid artery stenosis was carried out using Doppler ultrasonography, while infarct volume measurements were derived from diffusion-weighted magnetic resonance imaging (MRI). The study also included a detailed analysis of plaque morphology—specifically evaluating echogenicity, surface irregularity, and textural features—through carotid Doppler imaging. Correlational analyses were conducted to explore associations between the percentage of carotid stenosis and infarct volume, as well as the relationship between distinct morphological characteristics of plaques and infarct burden. Understanding and quantifying carotid stenosis alongside plaque morphology can serve as vital tools in the stratification of ischemic stroke risk. Early identification of high-risk features and timely intervention may significantly contribute to the reduction of recurrent cerebrovascular events and guide individualized patient management strategies.

Results

The data was collected from 50 participants. The mean age of the study population was 61.04 years with a standard deviation of 12.87 years. The minimum and maximum ages were 29 and 90 years respectively. The age distribution of study participants is represented in figure I.

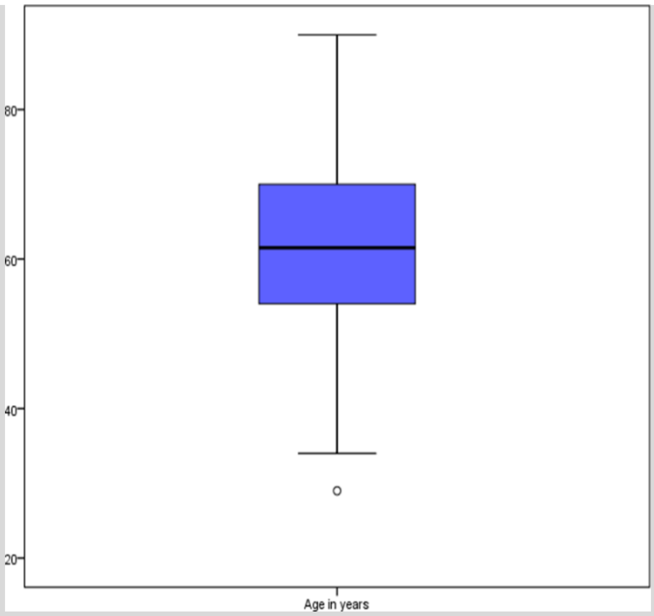

Figure I: Box-plot showing the age distribution of study participants (n = 50)

Carotid artery stenosis

Among 50 participants, 25 (50%) had stenosis in the right carotid artery and the remaining 25 (50%) had stenosis in the left carotid artery. The mean value of percentage of right carotid artery stenosis was found to be 62.2 with a standard deviation of 24.1. The mean and maximum values were found to be 30 and 90 while the median was 50.

When the percentage of stenosis of both right and left carotid arteries were combined together the mean value was found to be 57.2 with a standard deviation of 23.9. The minimum and maximum values were found to be 20 and 100 respectively. The median value was 50. The distribution of the percentage of left carotid artery stenosis is represented in figure II.

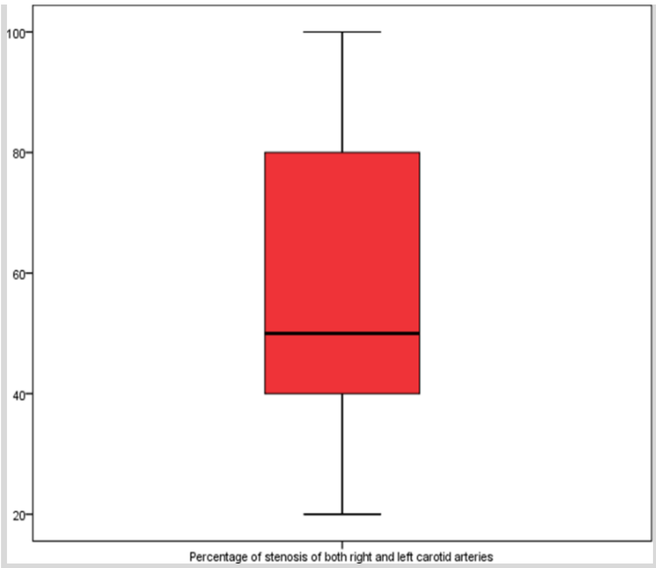

Figure II: Box-plot showing distribution of percentage of both right and left carotid arteries stenosis (n = 50)

The mean infarct volume was found to be 21.62 with standard deviation of 35.57. The minimum and maximum values were found to be 0.1 and 140.7 respectively. The median value was 3.7. The distribution of infarct volume is illustrated in figure III.

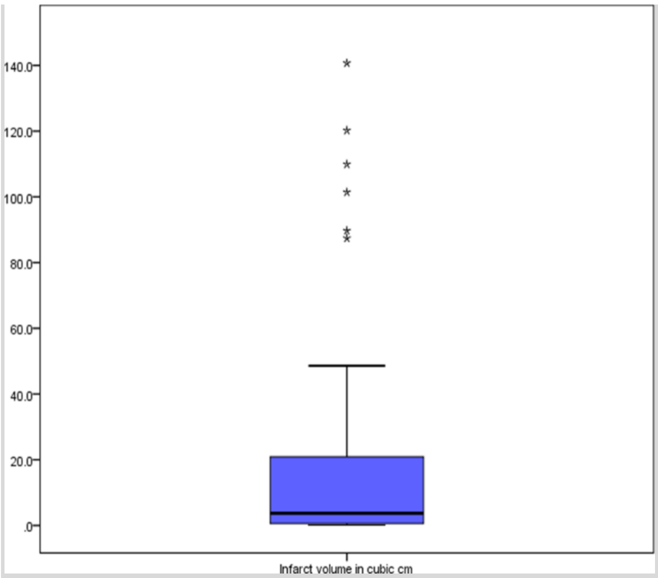

Figure III: Distribution of the infarct volume in study population (n = 50)

Table I: Descriptive statistics for the numerical variables in the study

Variable	N	Mean	Median	Standard deviation	Minimum	Maximum
Age	50	61.04	12.87	61.5	29.0	90.0
Percentage of RCA stenosis	25	62.2	50.0	24.1	30.0	90.0
Percentage of LCA stenosis	25	55.4	50.0	23.8	20.0	100.0
Percentage of both RCA and LCA stenosis	50	57.2	50.0	23.9	20.0	100.0
Infarct volume	50	21.62	3.7	35.57	0.1	140.7

RCA = Right Carotid Artery; LCA = Left Carotid Artery

Association between carotid artery stenosis and infarct volume
The study population was divided into three groups according to the percentage of carotid artery stenosis as follows,

1. Group 1: less than or equal to 50%
2. Group 2: between 51 to 69%
3. Group 3: equal to or greater than 70%

In the right carotid artery stenosis among 25 study participants, 10 came under group1, 5 under group 2 and the remaining 10 under group 3. Kruskal Wallis test was performed. It was found that the mean value of infarct volume increased from group 1 to group 2 and then to group 3 which had the highest infarct volume. It was found that there was significant difference in infarct volume within these groups with P value of 0.003. The results are represented in table II.

Table II: Association between right carotid artery stenosis groups and infarct volume

Group	N	Mean	Median	SD	P value
1	10	14.32	3.25	31.11	0.003
2	5	30.02	4.60	51.01	
3	10	51.65	30.65	42.54	

In the left carotid artery stenosis among 25 study participants, 13 came under group1, 6 under group 2 and the remaining 6 under group 3. Kruskal Wallis test was performed. It was found that the mean value of infarct volume was highest in group 3 followed by group 1 and then group 2. But, it was found that there was no significant difference in infarct volume within these groups with P value of 0.231. The results are represented in table III.

Table III: Association between left carotid artery stenosis groups and infarct volume

Group	N	Mean	Median	SD	P value
1	13	21.89	2.80	36.62	0.231
2	6	0.97	0.60	0.67	
3	6	25.49	8.50	37.81	

r: P-Pearson correlation coefficient; N- frequency, SD- standard deviation

When both right and left carotid artery stenosis groups were combined together, out of 50 study participants, 23 came under group 1, 11 participants under group 2 and 16 under group 3. Kruskal Wallis test was performed to determine if there were any significant differences in infarct volume between carotid stenosis artery groups. It was found that the mean value of infarct volume was highest in group 3 followed by group 1 and then group 2. It was found that there was significant difference in infarct volume within these groups with a P value of 0.013. The results are represented in table IV.

Table IV: Association between carotid artery stenosis groups and infarct volume

Group	N	Mean	Median	SD	P value
1	23	18.6	2.8	33.79	0.013
2	11	14.17	1.9	35.66	
3	16	31.06	16.1	38.21	

P-Pearson correlation coefficient; N- frequency, SD- standard deviation

Correlation between infarct volume and percentage of carotid stenosis
Spearman's correlation test was used to find the correlation between the percentage of carotid artery stenosis and infarct volume. For the right carotid artery it was found to be 0.355 with a P value of 0.081. The correlation for the left carotid artery stenosis was found to be 0.154 with a P value of 0.463. When both the right and left carotid artery stenosis were taken together, there was a significant correlation of 0.446 with a P value of 0.035. These results are illustrated in figure IV.

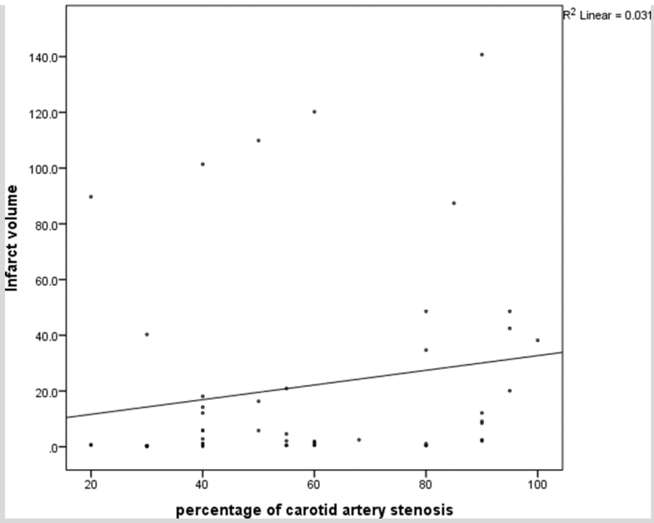

Figure IV: Correlation between infarct volume and percentage of carotid artery stenosis (n = 50)

Multiple regression analysis
The multiple regression analysis was used to predict the infarct volume in consideration of the carotid stenosis percentage and age in combination, infarct volume was the dependent variable and age and carotid stenosis percentage were independent variables. Considering age and carotid stenosis percentage together, it is seen that the accuracy of the prediction of infarct volume was 48%. Thus, it was established that there was a significant correlation with a P value of 0.025. The results are given in table V.

Table V: Correlations between age, carotid stenosis percentage and infarct volume

	Regression coefficient	Standard error of regression coefficient	P value
Model constant	3.634	5.070	0.025
Age	0.019	0.069	0.018
Percentage of carotid stenosis	0.103	0.038	0.010

P-Pearson correlation coefficient

Plaque morphology
When echogenicity of plaque is considered, majority of the study population had type 4, 19 (38%), followed by type 3 at 17 (34%) and type 2, 14 (28%). When surface of the plaque was studied, most of them 38 (76%) were irregular and regular surface was found in only 12 (24%) plaques. Among plaque texture, majority 30 (60%) had heterogenous texture and homogenous texture was found in 20 (40%). Ulcerative plaques were found in 2 (4%) and circumferential plaque was present in 1 (2%) individuals.

Association between carotid plaque morphology and infarct volume
Kruskal wallis test was performed to find the association between carotid plaque morphology and infarct volume. There was no significant association between these variables,

- Infarct volume and plaque echogenicity - P value of 0.168
- Infarct volume and plaque surface - P value of 0.910
- Infarct volume and plaque texture - P value of 0.812.

Discussion

This investigation was carried out within the Department of Radiodiagnosis at PSG Institute of Medical Sciences and Research, Coimbatore, spanning from January 2019 to June 2020. Fifty subjects fulfilling the inclusion criteria were enrolled. The study primarily aimed to examine the relationship between carotid artery stenosis, plaque characteristics, and the volume of cerebral infarction. Participants' ages ranged from 29 to 90 years, with a mean age of 61.04 years and a standard deviation of 12.87 years.

Carotid Artery Stenosis

Among the 50 participants, an equal distribution of stenosis was observed: 25 individuals (50%) had stenosis affecting the right carotid artery, while the remaining 25 (50%) exhibited stenosis in the left carotid artery. These proportions are comparable to those documented by Alagoz et al., who reported stenosis incidence of 44% on the right and 55% on the left carotid artery, as determined through CT angiography correlated with infarct volume assessed by MRI [5,13]. In the present study, the mean stenosis percentage was 62.2% (SD = 24.1%) for the right carotid artery and 55.4% (SD = 23.8%) for the left, both lower than the figures reported by Alagoz et al., which were 72.6% and 75.2%, respectively [14]. When considering stenosis in both carotid arteries collectively, the average degree was 57.2% (SD = 23.9%), again falling short of the 74% mean stenosis noted by Alagoz et al. [3,15].

Association between Carotid Artery Stenosis and Infarct Volume

The mean infarct volume calculated in this study was 21.62 (SD = 35.57), with values ranging from 0.1 to 140.7. These findings contrast with those of Alagoz et al., who observed a considerably smaller mean infarct volume of 4.4, with minimum and maximum values of 1.5 and 17.7, respectively [16]. The Kruskal-Wallis test revealed statistically significant differences in infarct volume across categories of stenosis severity for the right carotid artery ($P = 0.003$), which differs from Alagoz et al.'s report of no significant variation ($P = 0.096$) [17]. Conversely, no significant differences in infarct volume were found for the left carotid artery stenosis groups ($P = 0.231$), in agreement with Alagoz et al.'s results ($P = 0.234$) [18]. When stenosis of both carotid arteries was analyzed together, a significant difference in infarct volume was detected ($P = 0.013$), consistent with Alagoz et al.'s findings ($P = 0.004$) [19].

Spearman's correlation coefficients showed a moderate positive but non-significant relationship between right carotid artery stenosis and infarct volume ($r = 0.355$, $P = 0.081$), and a weak non-significant correlation for the left carotid artery ($r = 0.154$, $P = 0.463$). However, pooling data from both arteries demonstrated a significant correlation of 0.446 ($P = 0.035$). These observations align with Alagoz et al., who similarly found no significant correlation for either carotid artery individually (left: $r = 0.331$, $P = 0.098$; right: $r = 0.381$, $P = 0.088$), but a significant correlation when both arteries were considered in combination ($P = 0.001$) [19,20].

Multiple regression analysis incorporating age and carotid stenosis percentage accounted for 48% of the variance in infarct volume and yielded a statistically significant model ($P = 0.025$). This finding corroborates the work of Alagoz et al., who reported a predictive accuracy of 55% with a similar analytic approach [21]. Additionally, Bhagat et al., in a cohort of 100 patients with acute arterial stroke or transient ischemic attack, identified that 75% of patients with less than 50% stenosis had small infarcts, while 70% of those with stenosis exceeding 50% presented with larger infarcts, thus reinforcing the association between infarct size and carotid stenosis severity [22].

Similarly, Ahmed et al. evaluated carotid stenosis and infarct size correlations using Doppler ultrasound and CT imaging in 62 patients. Their findings revealed a positive association between increasing stenosis percentage and infarct size, with patients having ≥50% stenosis more frequently exhibiting large infarcts. Infarcts were stratified into small (<1.5 cm), medium (1.5-3 cm), and large (>3 cm), with the larger infarcts predominantly observed in the higher stenosis group [23].

Plaque Morphology

In the present study, plaques were primarily categorized as type 4 (38%, n = 19), followed by type 3 (34%, n = 17), and type 2 (28%, n = 14). This distribution contrasts with Bhagat et al., who reported type 2 plaques as the most prevalent subtype in stroke patients (31.2%) [12]. Regarding plaque surface characteristics, 76% (n = 38) of plaques exhibited irregular surfaces, while 24% (n = 12) had smooth surfaces. These findings are consistent with Bhagat et al.'s observations, which identified a predominance of irregularly surfaced plaques (43.7%) in stroke cases [2]. Concerning plaque texture, 60% (n = 30) were heterogeneous, whereas 40% (n = 20) were homogeneous.

Association between Carotid Plaque Morphology and Infarct Volume

No statistically significant association emerged between plaque morphology and infarct volume in this study. This diverges from Ahmed et al.'s results, where a significant relationship was found between homogeneous hypoechoic plaques and larger infarcts [7]. Ahmed et al. reported homogeneous hypoechoic plaques as the most common plaque type, whereas our cohort primarily exhibited stable plaques characterized by uniform echogenicity (type 4 plaques). Plaque features linked to larger infarct sizes include ulceration, hypoechogenicity due to lipid-rich necrotic cores, and intraplaque hemorrhage. Only two ulcerated plaques were identified in our sample, and the relatively small sample size may have limited the power to detect significant associations.

This investigation establishes a significant positive correlation between the extent of carotid artery stenosis and infarct volume when data from both the right and left carotid arteries are combined, yielding a correlation coefficient of 0.446. This result aligns with previous research, including that of Alagoz et al., which documented a comparable relationship. Although carotid stenosis demonstrates a notable association with infarct volume, no statistically significant link was identified between infarct size and carotid plaque morphology parameters such as echogenicity, texture, or surface irregularities.

The predominant plaque types observed in patients experiencing acute ischemic stroke were type 4 plaques, characterized by uniform echogenicity, plaques with irregular surfaces, and those exhibiting heterogeneous textures. Despite the frequent occurrence of these morphological features, their direct correlation with infarct volume was not statistically significant, implying that while plaque morphology may contribute to stroke pathogenesis, its impact on infarct volume remains inconclusive and warrants further detailed exploration.

In conclusion, Carotid Doppler ultrasonography continues to be an invaluable non-invasive modality for assessing carotid stenosis and plaque morphology in the context of acute ischemic stroke. Its capacity to quantify stenosis severity and delineate plaque characteristics underscores its critical role in stroke evaluation and management. Nonetheless, limitations exist, particularly regarding the precise characterization of plaque morphology, which should be acknowledged in clinical interpretation. Future research employing larger cohorts and advanced imaging modalities may provide more definitive insights into the interplay between plaque features and infarct volume.

Declarations

Ethical Clearance

The study was reviewed and approved by the Institutional Human Ethics Committee (IHEC) of PSG Institute of Medical Sciences and Research, Coimbatore. The approval reference number is PSG/IHEC/2019/Appr/fb/008, dated 4th January 2019. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments.

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Nil

Conflicts of Interest

Nil

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Nil

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References

[1] Truelsen T, Begg S, Mathers C. The global burden of cerebrovascular disease. Global burden of disease 2000. Cerebrovascular disease. 2006.

[2] Ojaghihaghighi S, Vahdati SS, Mikaeilpour A, Ramouz A. Comparison of neurological manifestation in patients with hemorrhagic and ischemic stroke. World J Emerg Med 2017; 8: 34-38.

[3] Sztajzel R. Ultrasonographic assessment of the morphological characteristics of the carotid plaque. Swiss Med Wkly 2005; 135: 635-643.

[4] Demarco JK, Ota H, Underhill HR, Zhu DC, Reeves MJ, Potchen MJ, et al. MR carotid plaque imaging and contrast-enhanced MR angiography identifies lesions associated with recent ipsilateral thromboembolic symptoms: An in vivo study at 3 T. Am J Neuroradiol 2010; 31: 1395-1402.

[5] Alagoz AN, Acar BA, Acar T, Karacan A, Demiryurek BE. Relationship between carotid stenosis and infarct volume in ischemic stroke patients. Med Sci Monit 2016; 22: 4954-4959.

[6] Zhao H, Zhao X, Liu X, Cao Y, Hippe DS, Sun J, et al. Association of carotid atherosclerotic plaque features with acute ischemic stroke: A magnetic resonance imaging study. Eur J Radiol 2013; 82: e564-e570.

[7] Ahmed L, Noori FA. Carotid Doppler study in patients with cerebral infarction. Fac Med Baghdad 2011; 53: 47-51.

[8] Harrigan MR, Deveikis JP. Contemporary Medical Imaging. In: Handbook of Cerebrovascular Disease and Neurointerventional Technique. New York: Springer; 2009. p. 3.

[9] Shapiro M, Becske T, Riina HA, Raz E, Zumofen D, Jafar JJ, et al. Toward an Endovascular Internal Carotid Artery Classification System. Am J Neuroradiol 2014; 35: 230-236.

[10] Wolpert SM. The circle of Willis. Am J Neuroradiol 1997; 18: 1033-1034.

[11] Osborn AG. Diagnostic Cerebral Angiography. 2nd ed. Philadelphia: Lippincott; 1999.

[12] Alpers BJ, Berry RG. Circle of Willis in cerebral vascular disorders: The anatomical structure. Arch Neurol 1963; 8: 398-402.

[13] Marinkovic S, Milisavljevic M, Marinkovic Z. Branches of the anterior communicating artery. Microsurgical anatomy. Acta Neurochir (Wien) 1990; 106: 78-85.

[14] Gloger S, Gloger A, Vogt H, Kretschmann HJ. Computer-assisted 3D reconstruction of the terminal branches of the cerebral arteries. I. Anterior cerebral artery. Neuroradiology 1994; 36: 173-180.

[15] Harrigan MR, Deveikis JP. Contemporary Medical Imaging. In: Handbook of Cerebrovascular Disease and Neurointerventional Technique. New York: Springer; 2009. p. 49.

[16] Gibo H, Lenkey C, Rhoton AL Jr. Microsurgical anatomy of the supraclinoid portion of the internal carotid artery. J Neurosurg 1981; 55: 560-574.

[17] Djulejic V, Marinkovic S, Georgievski B, Stijak L, Aksic M, Puskas L, et al. Clinical significance of blood supply to the internal capsule and basal ganglia. J Clin Neurosci 2016; 25: 19-26.

[18] Duan S, He H, Shaomao LV, Chen L. Three-dimensional CT study on the anatomy of vertebral artery at atlantoaxial and intracranial segment. Surg Radiol Anat 2010; 32: 39-44.

[19] Balyasnikova S, Fischer BM, Nijs RB. PET/MR in oncology: An introduction with focus on MR and future perspectives for hybrid imaging. Am J Nucl Med Mol Imaging 2012; 2: 458-474.

[20] Lee W. General principles of carotid Doppler ultrasonography. Ultrasonography 2014; 33: 11-17.

[21] Aljubawii AAAA, Hussein HN, Al-Alwany AA. Prevalence of coronary artery disease in patients with left bundle branch block and its association with risk factors hypertension and diabetes mellitus. Med J Babylon 2023; 20: 867-870.

[22] Alabdaly MA, Ahmed HM, Thanoun BI, Al Ashow SAM, Ahmad WG. Frequency of stroke and distribution of its subtypes in Nineveh, Iraq, related to risk factors. Med J Babylon 2024; 21(Suppl 2): S234-S237.

[23] Aljubawii AAA, Ali AI, Al Mamuri HAE. Relationship between modifiable atherosclerotic cardiovascular risk factors and coronary artery bifurcation lesion. Med J Babylon 2023; 20: 777-783. doi: 10.4103/MJBL.MJBL_481_23.

[24] Natarajan I, Rajendran K, Narayanan S, Shanmugam J. Swachh Bharat Mission Gramin: Uptake and challenges in rural Coimbatore. J Fam Med Prim Care 2024; 13: 4539-4544. doi: 10.4103/jfmpc.jfmpc_91_24.

[25] Charles J, Rajendran K, Osborn J. An Internal Audit on Patient Safety and Quality of services in a Rural Health Training Center, Coimbatore. Digit J Clin Med 2024; 6: [no page]. doi:10.55691/2582-3868.1175.

[26] Balasundararaj D, Prabhu MS, Thilagarajan S, Rajendran K. Analysis of Preanalytical Errors in Clinical Biochemistry Laboratory of a Tertiary Care Hospital: A Retrospective Study. J Clin Diagn Res 2024; 18: BC06-BC09. doi:10.7860/JCDR/2024/73364/20384.