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Original Article

Evaluation of extracranial carotid atheromatous plaque and stenosis in patients with acute ischemic stroke

Shakhawat Hossain[1*], Laila Yeasmin[1], Ahmed Imran[2], Arif Ahmed[3], Bibekananda Halder[1]

[1]*Department of Radiology and Imaging, Sir Salimullah Medical College & Mitford Hospital, Dhaka, Bangladesh.*
[2]*Department of Radiology and Imaging, Comilla Medical College & Hospital, Comilla, Bangladesh.*
[3]*Department of Radiology and Imaging, M A G Osmani Medical College, Sylhet, Bangladesh.*

Abstract

Background and Objective: Acute ischemic stroke remains a leading cause of death and disability worldwide. The development of atherosclerotic changes in the extracranial carotid arteries, such as increased intima-media thickness (IMT), atheromatous plaque formation, and stenosis, is a significant contributor to cerebral ischemia. These vascular alterations are crucial in the pathophysiology of ischemic stroke, as they can lead to embolic events and impaired blood flow to the brain. Colour duplex ultrasonography is a non-invasive, widely accessible, and reliable diagnostic tool for detecting and assessing these carotid artery changes. The primary aim of this study was to evaluate the causes and characteristics of carotid stenosis in patients diagnosed with acute ischemic stroke.

Materials and Methods: This cross-sectional observational study was conducted at the department of Radiology and Imaging at Sir Salimullah Medical College and Mitford Hospital, Dhaka, Bangladesh, from July 2021 to June 2023. A total of 52 patients who presented with acute ischemic stroke, confirmed through clinical and radiological diagnostic tests, were selected using purposive sampling. Colour duplex ultrasound was employed to assess the extracranial carotid arteries of all patients. The study collected data on sociodemographic factors, clinical presentation, vascular risk factors, carotid IMT, plaque characteristics, plaque location, and the severity of carotid stenosis.Statistical analysis was performed using SPSS version 26.0.

Results*:* The most common presentation was unilateral weakness (88.5%), with other features including dysphonia, unsteadiness, and dysphagia. Hypertension was the most prevalent vascular risk factor (65.4%).The middle cerebral artery (MCA) territory was the most frequently affected vascular region. Carotid IMT was found to be increased in 67.0% of patients, while atheromatous plaques and carotid stenosis were observed in 53.8% and 76.9% of patients, respectively. Most stenoses were mild, with less than 50% stenosis reported in the majority of cases. Carotid plaques were predominantly located at the carotid bifurcation, and these plaques were strongly associated with stenosis ($p<0.001$). Furthermore, carotid stenosis was significantly associated with older age, hypertension, dyslipidemia, and increased carotid IMT.

Conclusion*:* The study demonstrates a high prevalence of carotid atherosclerosis in stroke patients, with an observed association between stenosis and risk factors like age, hypertension, and dyslipidemia. However, the cross-sectional design precludes establishing causality.

***Correspondence**: *Shakhawat Hossain, Sir Salimullah Medical College & Mitford Hospital, Dhaka, Bangladesh. Email: dr.shakhawathoss@gmail.com.*

Introduction

Stroke is a major cause of death and long-term disability worldwide and remains a substantial public health burden, particularly in low- and middle-income countries [1]. Clinically, stroke is defined as the sudden onset of a focal neurological deficit of vascular origin lasting more than 24 hours and is broadly classified into ischemic and hemorrhagic types. Among these, ischemic stroke accounts for the majority of cases and is most commonly associated with thromboembolic occlusion of cerebral arteries [2].

Atherosclerotic disease of the extracranial carotid arteries is a key mechanism underlying ischemic stroke. Structural vascular changes such as increased carotid intima-media thickness (IMT), atheromatous plaque formation, and luminal stenosis reflect progressive arterial injury and are closely linked with cerebral ischemic events [3]. The risk of stroke is particularly elevated in individuals with significant carotid stenosis and concomitant vascular risk factors, including hypertension, diabetes mellitus, dyslipidaemia, and smoking [4,5]. Early detection of carotid atherosclerosis is therefore essential for risk stratification, prevention of recurrent cerebrovascular events, and identification of patients who may benefit from more intensive medical or surgical interventions [5,6].

Colour duplex sonography is a safe, non-invasive, accessible, and cost-effective imaging modality for evaluating extracranial carotid artery disease [4,6]. It enables comprehensive assessment of carotid IMT, plaque presence, plaque morphology, plaque location, flow characteristics, and the degree of luminal stenosis. In addition to estimating the severity of stenosis, duplex sonography provides valuable information on plaque characteristics that may reflect atherosclerotic burden and potential embolic risk [3,6,7].

Several regional studies have reported variable frequencies of carotid plaque and stenosis among patients with ischemic stroke; however, data remain limited in the local context. More importantly, existing studies have often focused on individual parameters rather than providing an integrated evaluation of carotid IMT, plaque characteristics, and degree of stenosis in relation to clinical presentation and vascular risk factors. This lack of comprehensive, locally relevant data limits a clear understanding of the overall burden and pattern of extracranial carotid atherosclerosis in patients with acute ischemic stroke [5,8].

Despite existing studies on carotid atherosclerosis in ischemic stroke, there is a lack of comprehensive data integrating carotid IMT, plaque characteristics, and stenosis severity. The present study was designed to evaluate these parameters and their relationship with clinical features and vascular risk factors in Bangladeshi population.

Materials and methods

This cross-sectional observational study was conducted at the department of Radiology and Imaging, Sir Salimullah Medical College and Mitford Hospital, Dhaka, Bangladesh, in collaboration with the departments of Neuromedicine, Internal Medicine, and Emergency of SSMC from July 2021 to June 2023. The study aimed to evaluate the presence of extracranial carotid atherosclerotic changes in patients with acute ischemic stroke. A total of 52 patients, selected through purposive sampling, were included in the study. These patients exhibited clinical and radiological signs of acute ischemic stroke, confirmed by brain CT scans. Patients were recruited from those admitted to the hospital during the study period. Inclusion criteria focused on individuals presenting with acute ischemic stroke, while patients with head trauma, hemorrhagic stroke, intracerebral neoplasm, cerebral abscess, or cerebrospinal fluid obstruction as the cause of stroke were excluded.

Duplex ultrasonography of the extracranial carotid arteries was performed on all patients using a high-resolution linear transducer (7–12 MHz). Data were collected through a structured questionnaire and checklist, including sociodemographic information, clinical presentation, vascular risk factors, carotid intima-media thickness (IMT), plaque characteristics (location), and the degree of carotid stenosis. The collected data also included CT scan results, focusing on lesion localization and vascular territory. Doppler ultrasound measurements included peak systolic velocity (PSV), end-diastolic velocity (EDV), the PSV ratio of the internal carotid

artery (ICA) to the common carotid artery (CCA), and the percentage of stenosis in the ICA.

The data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were reported as frequency and percentage. To compare continuous variables between patients with and without carotid stenosis, the independent-samples t-test was used. The chi-square test or Fisher's exact test was applied for categorical variables, with a p-value of less than 0.05 considered statistically significant. The results were presented in tables and figures. Ethical approval for the study was obtained from the Ethical Review Committee of Sir Salimullah Medical College.

The inclusion criteria allowed for the enrollment of 2–3 patients per month in the Radiology and Imaging department at Sir Salimullah Medical College & Mitford Hospital, Dhaka, resulting in an estimated population of 60 patients over a 24-month data collection period. The required sample size was calculated using the modified Cochran formula for finite populations: If N is finite & less than 10,000 the required sample size would be smaller. In this case final sample estimated (nf) by using the following formula (Modified Cochran formula):

$$nf = \frac{n}{1+\frac{n-1}{N}} = \frac{384}{1+\frac{384-1}{60}} = 52.03 = 52 \text{ (targeted sample size)}$$

Where, nf = the sample size, when population is less than 10,000.

n= the sample size, when population is more than 10,000.

N = the estimate of population size.

The subjects were selected non-randomly.

Targeted sample size = 52. (Sarmah et al. 2013)

To compensate for the dropout of patients, inadequate data and instrumental fault the sample size was increased by 15%. So, the total sample size was = 52 + 7.8 = 59.8 = 60

where *n* represents the sample size for an infinite population and *N* is the estimated population size. To account for potential dropout and incomplete data, the sample size was increased by 15%, resulting in a final target sample size of 60. However, 3 patients refused the duplex ultrasonographic examination, 4 patients had incomplete studies due to restlessness and non-cooperation, and 1 patient was excluded due to infarction of variable ages observed on CT scan. Consequently, 52 patients were included in the study.

Purposive sampling was used to select patients who were clinically and radiologically confirmed to have acute ischemic stroke, as this specific population was of primary interest for evaluating carotid artery changes. Since this was a hospital-based study, the sampling approach enabled the inclusion of cases that were rich in information, suitable for in-depth evaluation of carotid artery conditions using duplex ultrasonography within the study's time and resource constraints.

Ultrasonographic Examination: Ultrasonographic assessments were performed by a single operator, ensuring consistency across all examinations. A linear transducer (7–12 MHz) was used to examine the carotid arteries, assessing IMT, atherosclerotic changes, plaque location, extent, and morphology. Doppler waveforms were recorded from the common carotid, external carotid, extracranial internal carotid, and vertebral arteries. The degree of stenosis in the ICA was evaluated using the ratio of the ipsilateral ICA to CCA.

The color Doppler study of the extracranial carotid arteries was conducted under the direct supervision of an expert radiologist. Patients were positioned in the supine position, with their necks exposed by tilting and rotating the head away from the side being examined, and the ipsilateral shoulder being dropped as far as possible. Long-axis views of the carotid vessels were obtained from anterior and posterolateral longitudinal transducer positions, while transverse views were captured from anterior, lateral, and posterior lateral approaches. All examinations were performed with a Doppler angle of less than 60 degrees.

On grayscale imaging, carotid IMT, atherosclerotic changes, and plaque characteristics—were evaluated. The color Doppler study focused on flow patterns, PSV, and EDV of the CCA and ICA. The percentage of stenosis was determined by calculating the ratio of the ipsilateral ICA to CCA.

Results

Table-1: *Sociodemographic characteristics of the study patients (n = 52)*

Variables	Frequency	Percentage
Age group (years)		
37-40	1	1.9
41-50	5	9.6
51-60	20	38.5
61-70	21	40.4
71-85	5	9.6
Gender		
Male	33	63.5
Female	19	36.5
Occupation		
Housewife	14	26.9
Business	20	38.5
Service	1	1.9
Retired	6	11.5
Others	11	21.2
Mean age: 61.0 ± 8.36 years		
Range: 37-85 years		

A total of 52 patients were included in the study. The mean age of the participants was 61.0 ± 8.36 years, with an age range of 37-85 years. Most patients were aged 51-70 years, accounting for 78.9% of the study population. Male patients predominated, comprising 63.5% of the participants, while females accounted for 36.5%. With regard to occupation, most participants were engaged in business (38.5%) or were housewives (26.9%), whereas smaller proportions were retired (11.5%), involved in other occupations (21.2%), or employed in service (1.9%).

Table-2: *Clinical presentation and risk factors of the study patients (n = 52)*

Variables	Frequency	Percentage
Clinical presentation		
Unilateral weakness/clumsiness	46	88.5
Dysphonia	4	7.7
Unsteadiness	3	5.8
Dysphagia	2	3.8
Bilateral weakness	1	1.9
Risk factors		
Hypertension	34	65.4
Diabetes mellitus	13	25.0
Dyslipidemia	19	36.5
Smoking	16	30.8
Family history of cardiovascular disease	18	34.6

Multiple clinical presentations and risk factors could be present in the same patient; therefore, percentages do not total 100%.

The most common presentation was unilateral weakness (88.5%), with other features including dysphonia, unsteadiness, and dysphagia. Hypertension was the most prevalent vascular risk factor (65.4%).

Table-3: *Vascular territory of stroke (n=52)*

Territory	Side	Frequency	Percentage
MCA	Right	17	48.6
	Left	18	51.4
ACA	Right	4	40
	Left	6	60
MCA + ACA	Right	2	50
	Left	1	25
	Bilateral	1	25
PCA	Right	2	66.7
	Left	1	33.3

The middle cerebral artery (MCA) was the most frequently affected vascular territory. Among MCA strokes, left-sided involvement (51.4%) slightly exceeded right-sided involvement (48.6%). The anterior cerebral artery (ACA) was affected in 19.2% of cases, while combined MCA + ACA territory involvement was observed in 7.7%. Posterior cerebral artery (PCA) strokes were less common (5.8%) and predominantly right sided (66.7%). These findings indicate a predominance of anterior circulation strokes in this cohort.

Table-4: *Carotid artery IMT and plaque characteristics (n = 52)*

Variables	Frequency / Mean ± SD	Percentage
Increased IMT	35	67.0
RCCA	14	40.0
LCCA	8	22.9
Both	13	37.1
Mean IMT (mm)		
RCCA	0.971 ± 0.20	
LCCA	0.925 ± 0.206	
Plaque presence		
Present	28	53.8
Absent	24	46.2
Plaque location (n = 28)		
CCA	6	21.4
Bifurcation	15	53.6
ICA	7	25.0

Increased intima-media thickness (IMT) was noted in 67.0% of patients. Unilateral increased IMT was observed in the right common carotid artery (RCCA) in 40.0%, left common carotid artery (LCCA) in 22.9%, and bilaterally in 37.1%. The mean IMT was 0.971 ± 0.20 mm in the RCCA and 0.925 ± 0.206 mm in the LCCA. Carotid plaques were detected in 53.8% of patients. Plaque distribution predominantly involved the carotid bifurcation (53.6%), followed by the internal carotid artery (25.0%) and common carotid artery (21.4%).

Table-5: *Distribution of carotid artery stenosis (n=52)*

Variables	Frequency	Percentage
Stenosis		
Present	40	76.9
Absent	12	23.1
Side of stenosis (n=40)		
Right ICA	16	40
Left ICA	11	27.5
Bilateral	13	32.5
Degree of stenosis (n=40)		
<50%	35	87.5
50–70%	4	10
Near total occlusion	1	2.5

Carotid artery stenosis was present in 76.9% of patients. Among these, right-sided stenosis accounted for 40%, left-sided 27.5%, and bilateral stenosis 32.5%. Most stenoses were mild (<50%) (87.5%), with 10% exhibiting moderate stenosis (50–70%) and only 2.5% having near-total occlusion. These findings indicate that mild stenosis is most common in this population, though the prevalence of bilateral involvement is clinically significant.

Table-6: *Association of clinical variables with carotid artery stenosis (n = 52)*

Variables	Stenosis Present (n=40)	Stenosis Absent (n=12)	p-value
Age (Mean ± SD)	63.4 ± 7.29	52.9 ± 6.54	<0.001
Gender			0.142
Male	26	7	
Female	14	5	
Plaque			<0.001
Present	28	0	
Absent	12	12	
Hypertension	29	5	<0.05
Diabetes mellitus	12	1	0.128
Dyslipidemia	18	1	0.021
Smoking	15	1	0.055
Family history of cardiovascular disease	13	5	0.558
Mean IMT RCCA (mm)	**1.033 ± 0.187**	**0.767 ± 0.049**	<0.001
Mean IMT LCCA (mm)	**0.977 ± 0.206**	**0.750 ± 0.052**	<0.001

In the present study, the gender distribution revealed that out of 52 cases, 33 (63.46%) patients were male and 19 (36.54%) were female, resulting in a male-to-female ratio of 1.7:1. Among the 40 patients with carotid stenosis, 26 (65%) were male and 14 (35%) were female, while among the 12 patients without stenosis, 7 were male and 5 were female. These findings align with a study conducted by Sultana et al. (2023), where out of 96 subjects, 64 (66.67%) were male and 32 (33.33%) were female. Similar male predominance has also been reported in several previous studies. Patients with carotid stenosis were significantly older than those without stenosis (63.4 ± 7.29 years vs 52.9 ± 6.54 years, $p<0.001$). Atheromatous plaque showed a significant association with carotid stenosis, as plaque was present in 28 of 40 patients (70.0%) with stenosis, whereas no plaque was detected in patients without stenosis ($p<0.001$). Hypertension ($p<0.05$) and dyslipidemia ($p=0.021$) were also significantly associated with stenosis. Mean IMT values were significantly higher in patients with stenosis than in those without stenosis, both for the RCCA (1.033 ± 0.187 mm vs 0.767 ± 0.049 mm, $p<0.001$) and the LCCA (0.977 ± 0.206 mm vs 0.750 ± 0.052 mm, $p<0.001$). Gender, diabetes mellitus, smoking, and family history of cardiovascular disease did not show statistically significant associations. These findings highlight older age, hypertension, dyslipidemia, plaque presence, and increased IMT as key factors associated with carotid stenosis. (graded according to the NASCET criteria)

Discussion

This cross-sectional observational study investigated extracranial carotid atherosclerotic changes, including carotid intima-media thickness (IMT), atheromatous plaque formation, and luminal stenosis, in patients with acute ischemic stroke. The results demonstrate a substantial burden of extracranial carotid atherosclerosis among patients with acute ischemic stroke. Nevertheless, the cross-sectional nature of the study limits these observations to associations within the studied cohort and precludes causal inferences or comparisons with non-stroke populations.

The study population showed a predominance of males (63.5%), with a male-to-female ratio of 1.7:1. Among patients with carotid stenosis, 65% were male. Similar male predominance has been reported by Sultana et al. (2023) (66.7% male), as well as in other regional studies [4,11,19]. However, in the present study, gender was not significantly associated with carotid stenosis, suggesting that male predominance may reflect differences in exposure to vascular risk factors or healthcare access rather than an independent effect of sex

The mean age of participants was 61.0 ± 8.36 years, with most patients between 51 and 70 years. Patients with carotid stenosis were significantly older than those without stenosis. This finding is consistent with Dabilgou et al. (mean age 63.5±11.7 years), as well as Fernandes et al. and Gawaad et al., who reported increased prevalence of carotid atherosclerosis and stroke in older populations [5,9,10]. Age-related vascular changes, including endothelial dysfunction and progressive atheroma formation, likely explain this observation.

Clinically, unilateral weakness or clumsiness was the most common presentation (88.5%), comparable to findings by Haque et al. [8]. This correlates with the predominance of middle cerebral artery (MCA) involvement observed in this study. Similar vascular territory distribution has been reported by Dabilgou et al. and Gyawali et al., where anterior circulation, particularly MCA infarction, was most frequent [9,13]. This is expected given the MCA's role in supplying motor cortical areas.

Hypertension was the most common vascular risk factor (65.4%), followed by dyslipidemia, smoking, family history, and diabetes mellitus. Among these, hypertension and dyslipidemia showed significant associations with carotid stenosis, consistent with findings from Khedr et al., Sarkar et al., and Bharathi and Gullapalli [11,12,20]. These studies similarly identified hypertension and dyslipidemia as key modifiable risk factors in patients with carotid artery disease. In contrast, diabetes mellitus and family history were not significantly associated in this study, while smoking showed a borderline relationship

Increased carotid IMT was observed in 67% of patients, and mean IMT values were significantly higher among those with stenosis. This aligns with Gyawali et al., who also reported a high prevalence

of increased IMT in ischemic stroke patients [13]. IMT is widely recognized as an early marker of atherosclerosis and may indicate increased vascular risk even before significant luminal narrowing develops.

Carotid plaque was identified in 53.8% of patients, most commonly at the carotid bifurcation. This distribution is consistent with previous studies [14–16], which attribute plaque formation in this region to disturbed flow and low shear stress. A strong relationship between plaque presence and stenosis was observed, supporting findings from other studies [14-16] that identify plaque as a key structural factor in luminal narrowing and embolic risk.

Carotid artery stenosis was present in 76.9% of patients, with the majority being mild (<50%). This pattern is comparable to studies by Das et al., Beizavi et al., and Bharathi and Gullapalli [11,17,18], which also reported a predominance of mild stenosis among ischemic stroke patients. Additionally, studies by Saad et al. and Sarkar et al. [19,20] have demonstrated a high frequency of carotid atherosclerosis detected by duplex ultrasonography in stroke populations. The high prevalence of stenosis in the present study highlights the burden of extracranial carotid disease among stroke patients, even when the degree of narrowing is not severe.

The middle cerebral artery was the most commonly affected vascular territory, followed by ACA and PCA, which is consistent with findings from Dabilgou et al. and Gyawali et al. [9,13]. This supports the clinical observation that anterior circulation strokes predominate and are closely related to extracranial carotid artery pathology.

In summary, this study demonstrates a high prevalence of extracranial carotid atherosclerotic changes among patients with acute ischemic stroke, with older age, hypertension, dyslipidemia, plaque presence, and increased IMT more frequently observed among those with carotid stenosis. These findings are consistent with previous literature and reinforce the value of colour duplex ultrasonography as a non-invasive tool for evaluating carotid artery disease in stroke patients. Early identification of these changes may aid in risk stratification and guide appropriate preventive strategies.

Limitations

This study has descriptive hospital based observational analysis from a resource limited setting rather than a novel mechanistic investigation. This study is subject to several limitations that should be considered when interpreting the findings. First, the single-center design and the relatively small sample size restrict the generalizability of the results. Additionally, the use of purposive sampling and the absence of a non-stroke control group further limit the ability to draw broad conclusions. Consequently, the findings should be regarded as correlational within the context of the stroke population, rather than indicative of causal relationships. Furthermore, the study did not incorporate logistic regression analysis, which could have provided a more robust evaluation of the predictors of carotid stenosis in stroke patients. Despite these limitations, the study remains clinically relevant, particularly because of its integrated assessment of carotid IMT, plaque characteristics and stenosis using duplex ultrasonography in acute ischemic stroke patients in Bangladesh.

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Conflict of interest

The authors declared that they have no financial, personal, or institutional conflicts of interest that could have influenced the preparation or outcomes of this study.

Ethical Approval

Ethical approval was obtained from the Ethical Review Committee of Sir Salimullah Medical College & Mitford Hospital, Dhaka, Bangladesh.

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