



TO ASSESS THE UTILITY OF COLOR DOPPLER ULTRASOUND IN STENO-OCCLUSIVE DISEASE OF EXTRA-CRANIAL CAROTID ARTERIES IN STROKE PATIENTS

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ABSTRACT

Background: Stroke is a clinical condition characterized by a sudden neurological deficit, usually caused by vascular issues. Key risk factors for stroke include diabetes, smoking, alcohol use, and hypertension. Color Doppler ultrasound plays a crucial role in evaluating extracranial carotid artery insufficiency, particularly in assessing carotid artery disease. This study aimed to evaluate and assess the utility of color Doppler ultrasound in diagnosing steno-occlusive disease of extracranial carotid arteries in stroke patients. **Material & Methods:** This analytic cross-sectional study involved 80 adult patients with clinical signs of stroke or a history of transient ischemic attacks (TIA). These patients were referred for Color Doppler evaluations of their extracranial carotid arteries to assess for atheromatous disease. The findings were then correlated with their cerebrovascular symptoms. Statistical analysis was performed to interpret the relationship between carotid artery disease and cerebrovascular conditions. **Results:** Among the 80 patients studied, 51.25% were male and 48.75% female, with 59% over the age of 61. Atherosclerotic plaques were identified in 80% of patients, while 20% showed increased intima-media thickness (IMT) without plaque formation. Of those with plaques, 62.5% had diabetes, 68.8% had hypertension, and 34.4% were smokers or alcohol users. The average IMT for patients with plaques was 1.36 mm, compared to 1.04 mm in patients without plaques. Peak systolic velocity findings indicated that 45.3% of patients had velocities below 125 cm/sec. Most patients had stenosis of less than 50%, while 35.9% exhibited 50-70% stenosis, and 6.3% had near-total occlusion. B-mode imaging revealed that type II plaques were the most prevalent (35.9%). **Conclusions:** Color Doppler ultrasound is an effective, non-invasive, and cost-efficient tool for evaluating the extracranial carotid arteries. Its use is beneficial in predicting cerebrovascular accidents (CVA) in patients with carotid atheromatous disease, offering a reliable method for diagnosis and prevention without side effects.

KEYWORDS : Color doppler ultrasound, steno-occlusive disease, extracranial carotid artery, stroke

INTRODUCTION

Stroke, a clinical syndrome characterized by a sudden neurological deficit with presumed vascular origin, is one of the leading causes of death globally. It significantly affects the quality of life, often leaving individuals with lasting impairments following a cerebrovascular accident (CVA). Cerebral ischemic stroke ranks as the third leading cause of death, after malignancies and cardiovascular diseases. [1]

Atherosclerosis in both intracranial and extracranial carotid vessels accounts for around 80% of all strokes. The risk of stroke is directly proportional to the degree of stenosis resulting from carotid atherosclerosis. [2] Atherosclerotic disease of the extracranial carotid arteries carries significant morbidity and mortality risk despite maximal medical therapy. NASCET demonstrated a stroke rate of 19–33% after 18 months of medical therapy without intervention among symptomatic patients, depending on the degree of stenosis. [3]

Unfortunately, many stroke survivors are left with severe, irreversible disabilities. [4] Several key risk factors contribute to the occurrence of stroke, including diabetes mellitus, smoking, alcohol consumption, and hypertension. [5] Interventional management consisting mainly of carotid endarterectomy (CEA) and carotid angioplasty and stenting (CAS) has been shown to decrease the stroke rate among these patients. [6]

Color Doppler ultrasound is a vital tool in assessing extracranial insufficiency of the carotid arteries. Its primary importance lies in accurately diagnosing hemodynamically significant stenosis, which is crucial for identifying patients who may require surgical intervention. As a low-cost, safe, and non-invasive diagnostic method, color Doppler provides significant value in the evaluation of carotid artery disease, making it an essential test for patients at risk of stroke. [7]

Conventional carotid angiography remains the gold standard for detecting carotid stenosis, yet it comes with notable disadvantages such as being invasive, expensive, and carrying risks associated with the use of contrast medium and

increased morbidity. While numerous studies suggest that contrast-enhanced MR angiography and CT angiography are promising alternatives to digital subtraction angiography, these methods are less cost-effective and are not typically considered the primary diagnostic choice. Duplex scanning has now emerged as the preferred initial investigative modality for stroke due to its combination of accuracy, safety, patient comfort, and cost-effectiveness. Additionally, duplex scanning is capable of assessing plaque morphology and complications like hemorrhage and ulceration, which elevate the risk of thromboembolic events. [8,9]

This study aimed to evaluate and assess the utility of color Doppler ultrasound in diagnosing steno-occlusive disease of extracranial carotid arteries in stroke patients. By utilizing color Doppler, the research focused on identifying the degree of stenosis, detecting vascular abnormalities, and correlating these findings with stroke occurrences. The goal was to determine the effectiveness of this non-invasive, cost-effective tool in providing reliable diagnostic information for patients with cerebrovascular accidents linked to carotid artery disease.

MATERIAL AND METHODS

Following approval from the institutional ethical committee, an analytical cross-sectional study was conducted over a period of 18 months, from 1st September 2022 to 29th February 2024, in the Department of Radiodiagnosis at SAIMS & PG Institute, Indore. The study included 80 adult patients presenting with clinical features of stroke or a history suggestive of transient ischemic attacks (TIA) who were referred for Color Doppler evaluation. Patients were enrolled based on the inclusion and exclusion criteria, and informed consent was obtained from the patients or their guardians after explaining the study protocol.

Inclusion Criteria

- All patients of adult age group presenting with clinical features of stroke or patients presenting with history suggestive of transient ischaemic attacks undergoing for Color Doppler, during study duration.

Exclusion Criteria

- Patients who are not willing to give consent;
- Patients who do not have stroke;
- Patients of pediatric age group; and
- Patients with evidence of hemorrhagic stroke were excluded.

Methodology

A pre-structured proforma was employed for collecting baseline data. Detailed patient histories were obtained and correlated with relevant laboratory investigations. Symptoms indicative of cerebrovascular disease, such as transient neurological dysfunction, sudden weakness or numbness, hemiparesis, focal neurological deficits, sudden loss of consciousness, altered sensorium, aphasia, slurred speech, and vision impairment or loss, were considered for inclusion in the study.

Carotid artery ultrasounds were performed using advanced machines (e.g., GE Logiq E9, GE Logiq F8 Expert, GE Logiq F6, and GE Voluson E8 Logiq E systems) with patients placed in a supine position with the head hyperextended and the neck either straight or obliquely positioned contralaterally for optimal visualization. Ultrasound examinations of the extracranial carotid arteries were performed using gray scale, color Doppler, and power Doppler imaging, with a high-frequency probe (7.5 to 10 MHz) to capture vessel anatomy and pathologies in both transverse and sagittal planes.

The examination involved two key steps. First, longitudinal and transverse B-mode images were taken to map the vessel course, detect wall thickening, and identify atheromatous plaques. The scan extended from the supraclavicular notch to the jaw, allowing visualization of the common carotid artery, subclavian, and vertebral arteries.

In the second step, color Doppler was used to assess hemodynamics and analyze pathological areas. Atheromatous plaques were examined for surface features and structural integrity by observing color flow along the lesion, aiding in the identification of significant pathology.

For each ultrasound examination, the velocity scale was meticulously adjusted to provide complete color coding of the flow lumen, avoiding aliasing. The system's sensitivity for detecting motion was tailored for each patient, setting it just above the level of color noise and then reducing it to just below the noise threshold. The gain was adjusted to ensure optimal surface color coverage on the vessel without causing color bleed.

Additionally, wall filter settings were verified. If these settings were too high, low-frequency signals generated by low-velocity flow could be eliminated. The wall filter was adjusted to ensure all necessary flow signals were captured. A peak frequency shift in the common carotid or internal carotid arteries, proximal to a stenotic lesion, was detected by positioning a small sample volume Doppler cursor in the center of the patent lumen.

To assess the degree of stenosis, the Doppler sample volume was repositioned in the area of maximum stenosis. The residual lumen and the total lumen at the same level were measured using electronic calipers to calculate the degree of stenosis. The technical settings for these evaluations were based on the manufacturers' default presets for carotid artery studies, ensuring accuracy and consistency across the examinations.

Transverse images of the carotid bulb, as well as the proximal and distal internal carotid arteries, were captured using grayscale, color Doppler, and power Doppler techniques. Measurements were taken at these key locations, with

additional measurements made at distances of 0.5 cm and 1.0 cm downstream. The angle cursor was aligned parallel to the outer wall of the internal carotid artery to ensure accurate Doppler readings. All findings were meticulously documented on a pre-structured proforma designed for the study.

Statistical Analysis

The data was coded and entered into Microsoft Excel 2010, and analyzed using both Excel and SPSS 22.0 for Windows. The study results were organized into tables and subjected to statistical analysis. Descriptive statistics were employed to identify characteristics and features of the collected data, with mean and percentage utilized for representation. A Chi-square test was applied to assess associations between variables, considering a p-value of less than 0.05 as statistically significant.

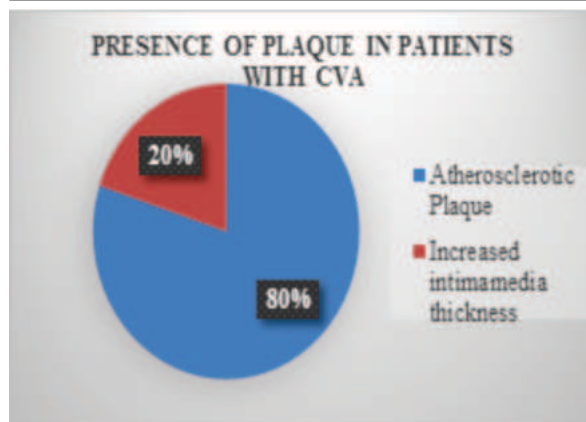
RESULTS

Of the 80 patients included in the study, 41 (51.25%) were males and 39 (48.75%) were females. Although there were slightly more males than females, this difference was not statistically significant. The majority of patients were above 61 years of age (59%), indicating that the elderly are more prone to cerebrovascular accidents (CVA). Twenty-four percent were between 51-60 years, and 12% were between 41-50 years. Only 1 patient was between 21-30 years. (Table 1)

Among the patients, 80% had the presence of atherosclerotic plaques, while 20% exhibited increased intima-media thickness without plaque. Among the 64 patients with atherosclerotic plaques, there was an equal distribution by gender, with 32 males and 32 females. (Graph 1)

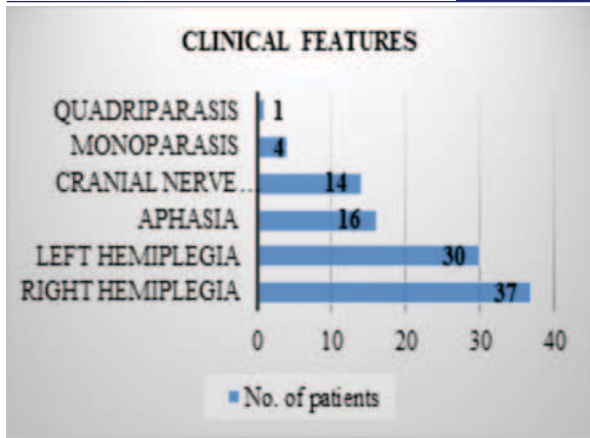
Table 1: Demographic Distribution Of The Patients With CVA.

Parameter	No of patients	Frequency (%)
Age		
21-30 years	1	1.25%
31-40 years	3	3.75%
41-50 years	10	12.5%
51-60 years	19	23.75%
>61 years	47	58.75%
Gender		
Male	41	51.25%
Female	39	48.75%



Graph 1. Distribution Of Patients With CVA Depending Upon Presence Of Plaque

The predominant clinical presentation among the 80 patients was right hemiplegia, observed in 37 patients (46.3%), followed by left hemiplegia in 30 patients (37.5%). Aphasia was noted in 16 patients (20%), cranial nerve palsy was observed in 14 patients (17.5%), monoparesis in 4 patients (5%) while quadriparesis was observed in only 1 patient (1.25%). (Graph 2)



Graph 2. Distribution Of Patients With CVA Depending Upon Clinical Features

Among the 64 patients with atherosclerotic plaque, 62.5% had diabetes and 68.8% had hypertension, with approximately 34% being smokers, alcoholics, or both. In contrast, among the 16 patients without plaque, over 37.5% also had diabetes and hypertension, while 31.3% were alcoholics and 25% were regular smokers. These findings highlight the strong association between atherosclerotic plaque formation and common cardiovascular risk factors, emphasizing the importance of comprehensive risk assessment in stroke patients (Table 1).

Table 2: Risk Factors Among Patients With CVA With And Without Plaque

Comorbidities	Patients with plaque (n=64)	Patients without plaque (n=16)
Diabetes	40 (62.5%)	6 (37.5%)
Hypertension	44 (68.8%)	6 (37.5%)
Smoking	22 (34.4%)	4 (25%)
Alcohol	22 (34.4%)	5 (31.3%)

The mean intima-media thickness among the 80 patients with carotid index was 1.36 mm, with a maximum measurement of 1.7 mm. In contrast, the stroke patients without plaque exhibited a mean intima-media thickness of 1.04 mm, with a maximum of 1.1 mm (Table 2).

Table 3: Intima Media Thickness (IMT) In Patients With And Without Carotid Plaque

Intima media thickness (IMT)	Mean (in mm)	Minimum IMT (in mm)	Maximum IMT (in mm)
In patients with plaque	1.36 + 0.5	1.2	1.7
In patients without plaque	1.04 + 0.2	1.0	1.1

Among the 64 patients with atherosclerotic plaque, 29 (45.5%) had a peak systolic velocity of <125 cm/sec, 23 (35.9%) exhibited a velocity between 125-130 cm/sec while 10 (15.6%) exhibited a peak velocity between 135-200 cm/sec. Only three patients had a peak systolic velocity exceeding 200 cm/sec. Additionally, 29 (45.3%) had an end diastolic velocity of <40 cm/sec, while 12 (18.8%) had velocities greater than 100 cm/sec. The carotid index or systolic velocity ratio was <2.0 in 29 (45.3%) patients and ranged from 2.0-4.0 in 23 (35.9%) patients. Twelve patients (18.8%) had an index greater than 4.0. Most patients i.e., 34 (53.1%) had one plaque formation, while 31.3% had two. The majority exhibited type II morphological grading based on gray scale B-mode imaging i.e., 23 (35.9%), followed by Type I in 17 (26.6%).

More than 50% stenosis was observed in 29 (45.3%) of the patients, while 23 (35.9%) exhibited stenosis between 50-70%. Near-total occlusion was identified in 4 (6.3%) of the patients, and none of the patients presented with complete occlusion (Table 3).

Table: 4: Radiological Evaluation Of Patients With Atherosclerotic Plaque

Features	Number	Percentage
Peak systolic velocity (cm/sec)		
< 125	29	45.3%
125-130	23	35.9%
135-200	9	14.1%
>200	3	4.7%
End diastolic velocity (cm/sec)		
<40	29	45.3%
40-100	23	35.9%
>100	12	18.8%
Carotid index		
<2.0	29	45.3%
2.0-4.0	23	35.9%
>4.0	12	18.8%
No. of plaques		
1	34	53.1%
2	20	31.3%
3	8	12.5%
4	2	3.1%
Type based on B-mode imaging		
Type I	17	26.6%
Type II	23	35.9%
Type III	12	18.8%
Type IV	12	18.8%
Diameter stenosis based on color doppler		
<50%	29	45.3%
50-70%	23	35.9%
>70%	8	12.5%
Near total occlusion	4	6.3%

DISCUSSION

In the present study, among the 80 patients assessed, 64 exhibited evidences of atherosclerotic plaque in their extracranial carotid arteries as determined by color Doppler evaluation, while 16 patients showed no signs of carotid atherosclerosis. Notably, the gender distribution among the patients with atherosclerotic plaque was equal, with 32 males and 32 females. This finding aligns with the study conducted by Bollipo JP et al. [1], who reported an incidence of 82% of atherosclerotic patients among 100 individuals in their research. The consistency of these results underscores the significant prevalence of atherosclerosis in patients presenting with cerebrovascular issues, emphasizing the need for effective screening and management strategies in this population. The high incidence of atherosclerosis further reinforces the relationship between carotid artery disease and the risk of cerebrovascular accidents, highlighting the importance of regular monitoring and early intervention in at-risk patients. However, contrasting results were reported by Sethi et al. [10], who reported a higher incidence of atherosclerosis in males compared to females. The disparity was attributed to the protective effects of female hormones, although it was noted that post-menopausal women experience a shift, leading to similar incidence rates in both genders. This highlights the influence of hormonal factors on the development of atherosclerosis and the importance of considering gender when evaluating stroke risk in patients. [11]

In this study, 58.75% of patients were aged 61 years and older, with 23.75% in their sixties, 12.5% in their fifties, 3.75% in their forties, and just 1.25% in their twenties. These findings are consistent with research done by Malik et al. [12] and Bollipo JP et al. [1], which also emphasized the age distribution among stroke patients. Additionally, Sethi et al. reported mean ages of 65.4 years for males and 66.1 years for females, further highlighting the link between age and stroke incidence. Fernandez et al. identified the 60-69 age group as the most affected, reinforcing the need for targeted prevention and management strategies for cerebrovascular

diseases in older adults.

Hemiplegia emerged as the predominant clinical presentation in this study, with 37 (46.3%) of patients exhibiting right-sided hemiplegia and 30 (37.5%) showing left-sided hemiplegia. Additionally, 16 (20%) of patients presented with aphasia, 14 (17.5%) with cranial nerve palsy, 4 (5%) with monoplegia, and 1 (1.25%) with quadriplegia. These findings align with a study by Malik et al. [12], where 41% had right hemiplegia, 35% had left hemiplegia, and aphasia was observed in 18% of patients, supporting the results of the current study. Bollipo JP et al. [1] also reported similar findings, identifying hemiplegia as the most common clinical presentation, with 35% of patients experiencing right hemiplegia and 28% with left hemiplegia. Additionally, aphasia was observed in 15% of the patients.

Among the patients with atherosclerotic plaque, 62.5% had diabetes, while 68.8% had hypertension. Approximately 34.4% of these patients were either smokers, alcoholics, or both. Notably, even among those without plaque, over 37.5% had diabetes and hypertension. Among this group, 31.3% were alcoholics and 25% were regular smokers. These findings align with a study by Fernandez et al. [13], which indicated that a significant proportion of patients (38%) had hypertension, further emphasizing the positive correlation between smoking and cerebrovascular conditions in his research. In a similar study, Bollipo JP et al. [1] reported comparable findings, identifying diabetes and hypertension as significant risk factors, alongside smoking and alcohol consumption.

A study by Mannami et al. [14] attributed 22% of stroke cases to smoking. In contrast, Lawes et al. [15] found a comparatively lower association between hypertension and stroke. Additionally, research by Lindsberg PJ et al. [16] revealed that two-thirds of ischemic stroke patients had diabetes mellitus.

The mean intima-media thickness (IMT) among patients with carotid plaque was found to be 1.36 mm, with a maximum measurement of 1.7 mm. In contrast, stroke patients without plaque exhibited a mean IMT of 1.04 mm, with a maximum of 1.1 mm. These findings align with a similar study by Sahoo et al. [17], which reported a mean IMT of 1.08 mm in stroke patients. Bollipo JP et al. [1] similarly reported that the mean intima-media thickness (IMT) among patients with carotid plaque was 1.38 mm, with a maximum measurement reaching 1.8 mm. In contrast, stroke patients without plaque showed a mean IMT of 1.07 mm, with a maximum of 1.2 mm.

Multiple plaques were observed in 46.9% of patients with cerebrovascular accidents (CVA), aligning with Malik R et al.'s study, which reported multiple plaques in 44% of stroke patients. [12] This finding is consistent with observations from Bhagat et al., and further supported by Al-Najim MM et al. [18] and Bollipo JP et al., [1] who found that 63% and 47.55% of stroke patients exhibited plaque in the extracranial carotid arteries. In the present study, Type I and Type II plaques were the most prevalent, accounting for nearly 62.5% of cases, whereas Malik et al. reported these types comprising 56% of their findings. However, Bollipo JP et al. [1] reported a similar incidence, noting that 64% of patients had Type I and Type II plaques identified through B-mode imaging.

Most patients in the current study presented with less than 50% stenosis, primarily attributed to Type I and Type II plaques. Stenosis greater than 70% was noted in 12.5% of cases, predominantly linked to Type I plaque. These results are consistent with finding from study done by Bollipo JP et al [12], and Malik et al.[12], and notably, none of the patients in the present study exhibited complete occlusion. In contrast, Fernandez et al. found that the majority of their patients had

stenosis ranging between 60-70%.

The study's limitations include a relatively small sample size and a single center study, which may hinder the generalizability of the results, and its observational nature, which does not establish a causal relationship between carotid atherosclerosis and cerebrovascular accidents.

CONCLUSION

Color Doppler sonography is a crucial, non-invasive tool for evaluating carotid artery conditions. It helps accurately locate plaques, assess plaque morphology, and determine the extent of stenosis in extracranial carotid arteries. This study found that 58.75% of patients were over 60, indicating an increased stroke risk in older adults. Additionally, 80% of patients with atheromatous plaques had experienced a cerebrovascular accident (CVA), highlighting a strong connection between carotid plaques and stroke. The average intima-media thickness (IMT) in CVA patients exceeded 1.05 mm, emphasizing its importance as a vascular health marker. Most patients had type I and II plaques, which carry a higher stroke risk. The study suggests that color Doppler assessments of carotid arteries can help predict strokes and guide prevention and treatment strategies. Incorporating this technique into routine clinical practice could improve stroke management and patient outcomes.

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