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Original Research Article

ROLE OF DUPLEX SONOGRAPHY IMAGING OF CAROTID VESSEL IN ASSESSING THE POTENTIALITY OF RECURRENCES IN CT DIAGNOSED STROKE PATIENTS

Kanugula Sahaja[1], Ramu C[2], Kucherlapati Lohith Sai Varma[3]

[1]Assistant Professor, Department of Radiodiagnosis, Great Eastern Medical School and Hospital, Srikakulam, Andhra Pradesh, India
[2]Assistant Professor, Department of Radiodiagnosis, Arunai Medical College and Hospital, Tiruvannamalai, Tamil Nadu, India
[3]Assistant Professor, Department of Radiodiagnosis, Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, Andhra Pradesh, India

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Corresponding Author:
Dr. Ramu C,
Assistant Professor, Department of Radiodiagnosis, Arunai Medical College and Hospital, Tiruvannamalai, Tamil Nadu, India.
Email: ramuhi51993@gmail.com

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ABSTRACT

Background: Stroke remains one of the leading causes of morbidity and mortality worldwide. Ischemic strokes accounts for approximately 85% of all cases of stroke. Atherosclerotic disease of the carotid arteries is a major source of thromboembolic events in these cases. While computed tomography (CT) is the primary modality for acute stroke diagnosis it lacks the capability to assess extracranial carotid pathology. Duplex sonography which is a non-invasive modality allows for detailed evaluation of carotid artery stenosis and plaque morphology. This study evaluates the role of duplex sonography in the identification of high-risk features associated with recurrent stroke potential in CT-confirmed stroke cases.

Materials and Methods: This prospective observational study was conducted at GEMS Hospital between December 2018 and March 2020. One hundred patients with CT-confirmed ischemic stroke underwent bilateral carotid duplex ultrasonography using a standardized protocol. Parameters assessed included intima-media thickness, plaque morphology, echogenicity, degree of stenosis, and hemodynamic changes. Patients with hemorrhagic stroke or pre-existing carotid artery disease were excluded.

Results: Among 100 patients (71 males, 29 females), the most common age group was 61–70 years. Hypertension (36%) and diabetes (26%) were the predominant comorbidities seen in patients. Carotid artery involvement was seen in 82% of cases and bilateral common carotid artery (CCA) involvement was found to be most frequent (51%). Mild (<50%) bilateral stenosis was the most common doppler finding. Echolucent (Type 3) plaques were seen in 58% of cases and most common location of these plaques was the posterior wall (74%). Severe stenosis (>70%) was uncommon but more frequently observed in internal carotid arteries (ICA).

Conclusion: Duplex sonography can provide crucial insights into plaque vulnerability and degree of stenosis in stroke cases. Its ability to detect high-risk morphological features makes it an important investigation in predicting recurrence risk. In resource-limited settings duplex imaging should be integrated into routine post-stroke evaluations to aid in secondary prevention strategies.

Keywords: Stroke, Carotid Stenosis, Ultrasonography, Recurrence, Atherosclerosis.

INTRODUCTION

Stroke remains one of the leading causes of death and long-term disability worldwide. The burden of these cases is reported to be disproportionately high in low- and middle-income countries. Stroke is characterized by the sudden onset of a focal neurological deficit persisting for more than 24 hours without any apparent cause other than a vascular origin.[1] It is usually categorized into ischemic (approximately 85% of cases) and hemorrhagic (approximately 15%) subtypes on the basis of etiology.[2] A significant proportion of ischemic strokes are found to be thromboembolic in origin with emboli most frequently originating from atherosclerotic plaques in the carotid arteries.[3] These plaques have been widely recognized as critical sites for atherothrombotic events leading to cerebral infarction. Given the increasing prevalence of atherosclerosis-related cerebrovascular disease particularly in aging populations and in rural areas with limited access to advanced diagnostics early detection and risk stratification are crucial for improving patient outcomes.

Duplex ultrasonography (DUS) of the carotid arteries has emerged as an important investigation for non-invasive assessment of carotid arteries. This imaging modality integrates traditional grayscale ultrasound to assess vessel wall morphology combined with color and spectral Doppler techniques to evaluate flow velocities and patterns. Intima-media thickness (IMT) is typically measured in the common carotid artery on longitudinal B-mode imaging.[4] Advanced plaque characterization using ultrasonography includes evaluation of echogenicity (hypoechoic, isoechoic or hyperechoic), presence of calcifications, ulcerations and intraplaque haemorrhage. All these ultrasounds and doppler features are linked to plaque vulnerability. These features provide valuable information beyond mere luminal narrowing and have been associated with a higher risk of cerebrovascular events. Moreover, quantification of percentage stenosis using peak systolic and end-diastolic velocity ratios across the carotid bulb remains the standard technique for assessing hemodynamic significance.[5]

Due to its non-invasive and real time nature duplex carotid sonography has largely replaced conventional angiography as the first-line diagnostic tool for evaluating suspected extracranial carotid artery disease in patients with cerebrovascular symptoms. It's also cost-effective, portable, and in expert hands have high accuracy. Given these advantages carotid duplex imaging is now routinely employed in screening patients with stroke or transient ischemic attack and is also used in follow-up to monitor progression or regression of disease. Importantly, duplex sonography not only facilitates the identification of high-risk plaques but also plays an important role in stratifying patients for interventions like carotid endarterectomy or stenting.[6]

Despite its utility there remains a substantial gap in awareness and utilization of carotid duplex sonography particularly in rural areas of developing countries including India. A significant portion of the stroke burden is reported from these regions. The matters are further complicated by delayed presentations, limited access to neuroimaging and lack of routine vascular screening programs in rural areas where facilities for such investigations are scarce.[7-9] Furthermore, while patients with CT-diagnosed stroke are often managed symptomatically they frequently do not undergo further evaluation for recurrent stroke risk.[10] This represents a critical shortcoming as recurrent strokes are not only more disabling but are also associated with higher mortality. Duplex sonography is an ideal modality for risk assessment and secondary prevention planning in such cases.

Given this context, the present study aims to evaluate the utility of duplex sonographic imaging of the carotid arteries in assessing the potential for recurrent strokes among patients who have already been diagnosed with stroke via computed tomography (CT).

MATERIALS AND METHODS

This hospital-based prospective observational study was conducted in the Department of Radiodiagnosis, GEMS Hospital. The duration of study was 2 years. A total of 100 patients with CT-confirmed ischemic stroke were included in the study on the basis of a predefined inclusion and exclusion criteria. All patients presenting with recent onset of neurological or vascular symptoms and were referred from the Department of General Medicine for carotid vessel evaluation using grayscale and color Doppler ultrasonography were included. Detailed case history including present illness and relevant past medical history was obtained from all participants prior to the examination.

Carotid doppler in all cases were performed using a DC-60 Mindray ultrasound system equipped with a high-frequency linear probe (≥5 MHz). Doppler settings were adjusted to obtain optimal flow visualization and spectral analysis. Each patient underwent a detailed bilateral carotid duplex sonography for assessment of presence of atherosclerotic changes as well as hemodynamic alterations. A uniform examination protocol was followed to maintain consistency as well as diagnostic accuracy. The technique of doppler ultrasound adhered to standards as recommended by the American Institute of Ultrasound in Medicine (AIUM), the Inter-societal Commission for the Accreditation of Vascular Laboratories (ICAVL) and American College of Radiology (ACR).

Patients were made to lie down in supine position on the examination table. Neck was kept slightly extended and the head was turned opposite to the side being examined. The transducer was positioned at

multiple angles that included anterolateral, lateral, and posterolateral sites depending on accessibility of carotid vessel. Posterolateral positioning provided optimal visualization of the carotid bifurcation and internal carotid artery while in some cases an anterolateral approach allowed improved imaging of the distal internal carotid segment. Longitudinal images were oriented with the patient's head displayed on the left side of the image and transverse images were oriented as if viewed from the patient's feet, with the right side of the patient shown on the left side of the display.

The carotid examination was done from the clavicle to the angle of the mandible in grayscale . It was followed by color Doppler mode to assess vessel anatomy and identify presence of any focal abnormalities. This was followed by a detailed longitudinal survey of the common carotid artery using a posterolateral approach. Spectral Doppler waveforms were obtained at mid-segment of the common carotid artery 2–4 cm below the bifurcation and another near the bulb. Appropriate angle correction was applied for accurate estimation of peak systolic velocity. Care was taken not to include sampling errors that could falsely alter the velocity ratio and lead to misinterpretation of internal carotid artery stenosis severity. Subsequently color flow imaging of the carotid bifurcation was performed in transverse sections to evaluate luminal patency, plaque morphology, flow disturbances and to differentiate between the internal and external carotid arteries based on their Doppler characteristics. Power Doppler was used in low-flow states or suspected occlusions to confirm vessel patency and detect minimal residual flow [Figure 1,2].

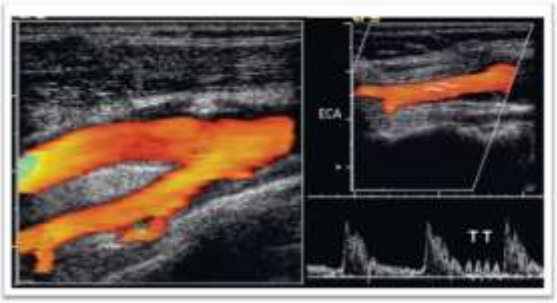

Figure 1: Normal ECA. A. Color Doppler ultrasound of CCA bifurcation demonstrating two small arteries arising from the ECA. B. Spectral Doppler shows the anticipated serrated (sawtooth) flow disturbance from the TT.

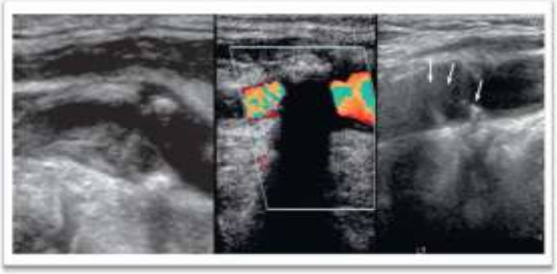

Image 2: Grayscale and Doppler Images showing (From Left to Right) a)Homogeneous, b)Calcified and c)Heterogeneous plaques.

All findings were documented systematically, including intima-media thickness, plaque morphology, echogenicity, calcification and presence of surface ulceration. Hemodynamic changes and velocity parameters were analyzed to determine the degree of luminal narrowing and assess the potential for recurrent ischemic events.

For statistical analysis SPSS 23.0 version was used and a p value less than 0.05 was taken as statistically significant.

Inclusion criteria:

- All CT-confirmed ischemic stroke patients referred from the Department of General Medicine for carotid vessel evaluation.
- Age of the patients above 18 years.
- Ready to give consent.

Exclusion criteria:

- Refusal to give consent.
- Patients diagnosed with hemorrhagic stroke on imaging.
- Patients with a known history of carotid artery disease or prior carotid intervention (endarterectomy/stenting).
- Uncooperative patients or patients with significant co-existing psychiatric illness.

RESULTS

Out of 100 studied cases there were 71 (71%) males and 29 (29%) females. There was male preponderance with M:F ratio of 1: 1.33. The most common age group in males was 71-80 years (23%) whereas in females most commonly affected age group was 51-60 years (12%). The mean age of male and female patients was found to be 64.7 +/- 11.7 and 58.1 +/- 10.2 years respectively. The difference in the mean age of male and female patients was found to be statistically significant (P = 0.0093) [Table 1].

Table 1: ?

Gender and Age Distribution		Male	Female	Total (100)
Age Groups	31–50 years	7 (7%)	5 (5%)	12 (12%)
	51–60 years	17 (17%)	12 (12%)	29 (29%)
	61–70 years	21 (21%)	9 (9%)	30 (30%)
	71–80 years	23 (23%)	3 (3%)	26 (26%)
	81–90 years	3 (3%)	–	3 (3%)
Total		71 (71%)	29 (29%)	100 (100%)
Mean Age (years)		64.7 +/- 11.7 years	58.1 +/- 10.2 years	
P= 0.0093 (Significant)				

The analysis of the co-morbidities among the studied stroke cases showed that hypertension was the most prevalent condition, observed in 36 patients (36%), followed by diabetes mellitus in 26 cases (26%). A combination of diabetes mellitus and hypertension was present in 20 individuals (20%), while 18 patients (18%) had a history of smoking and hyperlipidemia [Figure 1].

The analysis of carotid vessel laterality in the studied stroke patients revealed that involvement of the common carotid artery was most frequent, with bilateral affection seen in 51 cases (51%), left-sided involvement alone in 20 cases (20%), and right-sided involvement alone in 11 cases (11%), resulting in a total of 82 patients (82%) showing changes in the common carotid artery on at least one side. In comparison, the internal carotid artery was affected bilaterally in 21 cases (21%), with left-only involvement in 11 cases (11%) and right-only in 7 cases (7%), amounting to 39 patients (39%) with internal carotid artery changes. Overall, bilateral involvement was more common than unilateral, especially in the common carotid artery [Table 2]

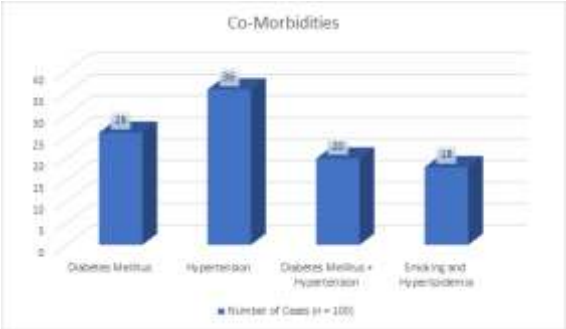

Figure 2: Co-Morbidities in studied cases.

Table 2: carotid vessel laterality in the studied stroke patients

Vessel	Right-only	Left-only	Bilateral	Total (any side)
Common carotid artery	11 (11%)	20 (20%)	51 (51%)	82 (82%)
Internal carotid artery	7 (7%)	11 (11%)	21 (21%)	39 (39%)

The analysis of the degree and pattern of carotid artery stenosis in the studied cases revealed that the most common type of involvement was bilateral stenosis of less than 50%, particularly in the right common carotid artery (40%) and the left common carotid artery (37%). In terms of higher-grade stenosis (>70%), the internal carotid arteries were more frequently involved, with the right ICA affected bilaterally in 7% and unilaterally in 3% of cases, and the left ICA showing bilateral involvement in 2% and unilateral in 3%. Stenosis between 50–69% was less frequent overall, with bilateral involvement noted in 8% of right CCA cases and 5% of right ICA cases. Unilateral stenosis of less than 50% was more commonly observed on the left side, with 15% in the left CCA and 6% in the left ICA, compared to 8% and 3% on the right CCA and ICA, respectively. Overall, mild stenosis (<50%) was the predominant finding, especially with bilateral distribution, while severe stenosis (>70%) was more often seen in the internal carotid arteries [Table 3,4].

Table 3: Degree of carotid artery stenosis in the studied cases.

Type of Involvement	Percentage of Stenosis	Right CCA	Right ICA	Left CCA	Left ICA
Unilateral	<50%	8 (8%)	3 (3%)	15 (15%)	6 (6%)
	50–69%	3 (3%)	1 (1%)	3 (3%)	2 (2%)
	>70%	–	3 (3%)	2 (2%)	3 (3%)
Bilateral	<50%	40 (40%)	9 (9%)	37 (37%)	11 (11%)
	50–69%	8 (8%)	5 (5%)	4 (4%)	3 (3%)
	>70%	3 (3%)	7 (7%)	6 (6%)	2 (2%)

Table 4: Pattern of carotid artery stenosis in the studied cases.

Parameter	Subcategory	Number of Cases (n = 100)
Vessel Wall Involvement	Anterior	5
	Posterior	74
	Circumferential	21
Plaque Classification	Type 1	0
	Type 2	0
	Type 3	58
	Type 4	42
	Type 5	0

The analysis of vessel wall involvement and plaque classification among the studied stroke patients showed a predominant involvement of the posterior wall (74%) followed by circumferential involvement (21%). Anterior wall involvement was seen in only 5 cases (5%). Type 3 plaques were the most commonly observed (58%) plaques followed by Type 4 plaques (42%). No cases of Type 1 (anechoic), Type 2 (mostly echolucent), or Type 5 (uniformly echogenic) plaques were identified [Table 4].

Table 5: Vessel wall involvement and plaque classification

Parameter	Subcategory	Number of Cases (n = 100)
Vessel Wall Involvement	Anterior	5
	Posterior	74
	Circumferential	21
Plaque Classification	Type 1 (anechoic – lipid-rich)	0
	Type 2 (mostly echogenic)	0
	Type 3 (predominantly hypoechoic with small echogenic areas – unstable/lipid-rich)	58
	Type 4 (predominantly echogenic with small hypoechoic areas – more stable/fibrous)	42
	Type 5 (uniformly echogenic – calcified)	0

DISCUSSION

In this prospective study of 100 CT confirmed ischemic stroke patients, carotid duplex In this prospective study of 100 CT-confirmed ischemic stroke patients, carotid duplex sonography revealed a predominance of mild (<50%) bilateral stenoses in the common carotid arteries and a substantial proportion of echolucent (Type 3) plaques (58%). These findings underscore that significant carotid pathology may exist even in patients who would not be classified as high-risk on the basis of solely on luminal narrowing. The distribution of plaque morphology is also important since it may suggest the presence of vulnerable, lipid-rich plaques even in presence of minimal luminal narrowing. These morphologies are increasingly recognized as predictors of cerebrovascular risk indicating the need for a broader, morphology-inclusive approach to post-stroke vascular risk stratification.

Observation of a high frequency of echolucent plaques being vulnerable for causing stroke aligns with earlier studies that have identified plaque echolucency as a significant independent predictor of stroke risk. Grønholdt et al demonstrated that Echolucent plaques causing >/=50% diameter stenosis by Doppler ultrasound is associated with increased risk of subsequent ipsilateral stroke, reporting a threefold increase in risk compared to patients with echogenic plaques, even when the degree of stenosis was comparable. The authors concluded that measurement of echolucency may improve selection of patients for carotid endarterectomy.[6] Similarly, Mathiesen et al found that echolucent plaques posed a higher risk for ischemic cerebrovascular events and this risk was independent of other risk factors, including the degree of stenosis and presence of co-morbidities.[8] Similarly the authors such as Sarzyńska Długosz I et al also reported that echolucent internal carotid artery plaques are a risk factor for ischaemic stroke irrespective of haemodynamics of blood flow.[9] In our cohort, the high prevalence of Type 3 plaques further supports the hypothesis that plaque vulnerability rather than consideration of isolated stenosis severity may play a pivotal role in recurrent stroke risk.

Interestingly, our study demonstrated that high-grade stenosis (>70%) was relatively uncommon particularly in the common carotid arteries. The results are consistent with the PARISK study where morphological plaque features such as intraplaque hemorrhage and overall plaque volume were reported to be stronger predictors of recurrent ischemic events than luminal narrowing alone.[10] Similarly, Nakamura et al reported that ulcerated echolucent plaques were associated with cerebrovascular thromboembolic events regardless of the percentage of stenosis.[11]

Duplex ultrasonography remains important non-invasive cerebrovascular evaluation in patients with history of stroke. Although our study did not incorporate Doppler indices like resistive or Pulsatality indices prior research by Chang et al has shown that such duplex-derived parameters can predict long-term outcomes in patients with carotid artery disease.[12] Similarly, the authors such as Nezu et al emphasized the utility of carotid ultrasonography not only in the acute diagnostic setting but also for ongoing risk assessment and treatment monitoring in patients with cerebrovascular disease.[13] Lin et al demonstrated that integrating sonographic plaque features with clinical variables can effectively stratify recurrent stroke risk, a direction that may be particularly applicable to rural populations with limited resources.[14] Similarly Qiao M et al also concluded that a risk prediction can be made on the risk of recurrent ischemic stroke based on characteristics of carotid plaques.[15]

The limitation of this study included absence of longitudinal follow-up which limited our ability to directly correlate sonographic findings with actual recurrence rates. Second, the lack of complementary advanced imaging (such as MRI or CT angiography) precluded the assessment of intraplaque hemorrhage or volumetric plaque analysis, which have shown strong prognostic value in other studies.

CONCLUSION

Duplex sonography of the carotid vessels is a reliable and non-invasive imaging tool for diagnosing carotid artery disease in cases of stroke. It offers valuable information on stenosis grading and plaque morphology. By identifying high-risk plaques duplex sonography plays an important role in management planning and secondary prevention particularly in

patients who are at higher risk for recurrent strokes and major cardiovascular events. Its accessibility and non-invasive nature makes it an ideal investigation modality for both initial evaluation and long-term follow-up in at-risk populations.

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