Original Article

DOI: 10.7860/IJARS/2023/62609.2888

Radiology Section

Evaluation of Carotid Arteries in Stroke Patients using Colour Doppler Sonography: A Cross-sectional Study

RAKESH VIJAYWARGIYA[1], GAURAV BHANDARI[2], VASUDEV LODHI[3], AKSHA TANWANI[4]

BY-NC-ND

ABSTRACT

Introduction: Cerebral ischaemic stroke is a neurological condition that can be fatal and debilitating and is one of the leading causes of morbidity and mortality. The major benefit of sonography is its capacity to describe plaque and identify plaques with increased risk of embolisation, in addition, to evaluate the degree of stenosis.

Aim: To diagnose and characterise the plaque morphology in extracranial portion of carotid arteries using colour Doppler sonography in patients with stroke.

Materials and Methods: A time-bound, hospital-based cross-sectional study was conducted in the Department of Radiodiagnosis, MGM Medical College and MY Hospital, Indore, Madhya Pradesh, India from August 2021 to July 2022. There were 80 stroke patients in the study. Risk factors like smoking, diabetes, hypertension, and family history were recorded. B-mode ultrasonography was used to assess carotid arteries and various Doppler parameters like Peak Systolic Velocity (PSV). Plaque characteristics and morphology like smooth margin, irregular margin, ulceration and haemorrhage were evaluated. Statistical parameters such as Student's t-test were used for association between ICA PSV and ICA/CCA PSV with degree of stenosis.

Results: Hypertension was the most common risk factor 57 (71.1%). A total of 54 (67%) stroke patients were found to have plaque in their carotid vasculature. A total of 21 (38.8%) of patients had type 3 plaque followed by type 1 plaque 14 (25.9%). Out of 67% of patients who had plaque, majority of patients 38 (47.5%) had <50% stenosis and 16 (29.6%) of patients had significant stenosis (>50%).

Conclusion: It was shown that carotid Doppler ultrasonography can be used as a screening tool for patients, who have risk factors for stroke to find asymptomatic carotid disease.

Keywords: Atherosclerosis, End diastolic velocity, Peak systolic velocity, Plaque

INTRODUCTION

According to the World Health Organisation (WHO), a stroke is "the sudden onset of clinical symptoms and signs of a localised neurological impairment lasting longer than 24 hours or proceeding to death with vascular origin be the cause" [1]. After cardiovascular diseases and cancer, it is the third most prevalent cause of death in India. It is also the main cause of disability in elderly persons. Atherosclerosis of the intra and extracranial carotid vessels, leading to cerebral infarction accounts for 80% of strokes, out of which 77% are due to extracranial vessels involvement [2]. The risk of large artery stroke is highest amongst patients with high degree of carotid stenosis, a history of diabetes and hypertension, presence of asymptomatic carotid plaques or a combination of these factors [3].

Carotid conventional angiography is the gold standard for detecting the severity of carotid stenosis, but it has its own disadvantages, as it is an invasive and expensive procedure with high radiation exposure and iodinated contrast. Magnetic resonance angiography is one of the major technique for evaluation of carotid vasculature but apart from being expensive, less readily available and time taking, it has its own technological limitations [4]. Duplex sonography combining high-resolution imaging and Doppler spectrum analysis has proved to be a easily available, non invasive, accurate, and cost-effective means of detecting and assessing carotid arterial disease [5].

The purpose of the present study was to diagnose the plaque morphology in carotid arteries using colour Doppler songraphy, in patients with stroke.

MATERIALS AND METHODS

A time-bound, hospital-based cross-sectional study was conducted in the Department of Radiodiagnosis, MGM Medical College and MY Hospital, Indore, Madhya Pradesh, India from August 2021 to July 2022 after receiving approval from Institutional Scientific and Ethical Committee (EC/MGM/JULY-21/41).

The study was carried out on 80 stroke patients. A thorough clinical history was obtained, and the results of the clinical examination were noted. Risk factors like dyslipidaemia, smoking, diabetes mellitus, and hypertension were noted.

Inclusion criteria: Patients who were either radiologically {Computed Tomography or Magnetic Resonance Imaging (CT or MRI)} and clinically diagnosed with stroke, patients who had suffered from ischaemic stroke, patients above 18 years of age and all the patients who give their consent to participate were included in the study.

Exclusion criteria: Patients with haemorrhagic stroke, patients with a history of head injury, stroke due to infections like Tuberculosis (TB), stroke due to brain tumours, stroke due to metabolic emergencies or stroke due to deep vein thrombosis and drug-induced stroke patients.

Study Procedure

Plaque characteristics and morphology like smooth margin, irregular margin, ulceration and haemorrhage were evaluated.

Plaques were classified into four types based on its echogenicity according to Gray Weale classification [6].

Type 1-Plaques have a thin rim over the surface but are predominantly anechoeic.

Type 2-Plaques have less than 25% echogenic components.

Type 3-Plaques have less than 25% hypoechoic components

Type 4-Plaques are predominantly echogenic.

A consensus conference in 2003 of the Society of Radiologists in Ultrasound recommended the following criteria for estimating stenosis [7]:

a) When the Internal Carotid Artery (ICA) PSV is <125 cm/s, no plaque or intimal thickening is visible sonographically, ICA/Common Carotid Artery (CCA) PSV ratio <2.0 and ICA End Diastolic Velocity (EDV) <40 cm/s the ICA was regarded as normal.

b) <50% ICA stenosis is diagnosed when: 1) ICA PSV is <125 cm/s; 2) plaque or intimal thickening is visible sonographically; 3) ICA/CCA PSV ratio <2.0; 4) ICA EDV <40 cm/s.

c) 50%-69% ICA stenosis is diagnosed when: 1) ICA PSV is 125-230 cm/sec; 2) plaque is visible sonographically; 3) ICA/CCA PSV ratio of 2.0-4.0; 4) ICA EDV of 40-100 cm/s.

d) ≥70% ICA stenosis but less than near occlusion of the ICA is diagnosed when: 1) ICA PSV is >230 cm/sec; 2) ICA/CCA PSV ratio >4; 3) ICA EDV >100 cm/sec.

In near occlusion of the ICA, the velocity parameters may not apply, and velocities may be high, low, or completely undetectable. This diagnosis is established mainly by demonstrating a markedly narrowed ICA lumen at colour/power Doppler ultrasound. Total occlusion of the ICA should be suspected, if there is no detectable patent lumen at the gray-scale ultrasound and no flow with spectral, power, and colour Doppler ultrasound. In the present study, the PSV of >125 cm/sec, PSV ratio of ICA/CCA >2 and the PSV of >230 cm/sec, PSV ratio of ICA/CCA >4 were taken to define the percentage of significant stenosis >50% and >70%, respectively [7].

Examination technique: Colour Doppler examination of the carotid arteries was done using 7 MHz linear array electronic transducer.

Patient position: While the patient was supine, the carotid arteries were inspected. The ipsilateral shoulder was dropped, as far as feasible, and the neck exposure was improved by tilting and turning the head away from the side being examined. At the patient's right-side, the examiner was seated.

The examination sequence: Using the transducer in a lateral position, the first stage begins with a longitudinal scan of the cervical carotid arteries. The transducer was pushed cephalad down the CCA, until the carotid bifurcation was seen after the CCA was located at the clavicle. The exterior and internal carotid arteries' identities were verified.

The posterolateral transducer position was used to trace the ICA as cephalad as possible. Each aberrant location underwent close examination to determine the extent of plaque formation, internal plaque characteristics, and degree of luminal narrowing (from colour Doppler and spectral Doppler information). By directly measuring the remaining lumen in the area of maximal stenosis and comparing it to the total lumen, the degree of stenosis was determined. A spectral analysis was performed at the location of the greatest stenosis, and the degree of stenosis was calculated based on velocity criteria.

STATISTICAL ANALYSIS

The Statistical Package for the Social Sciences (SPSS) version 26.0 was used. Statistical parameters such as student's t-test were used for association between ICA PSV and ICA/CCA PSV with degree of stenosis. The p-value of 0.05 or less was considered statistically significant.

RESULTS

In the present study, 59 (73.7%) patients were males and 21 (26.3%) were females. Most of the patients belong to 61-70 years of age group. The mean age was 64.07±10.62 years [Table/Fig-1]. Out of the 80 patients, 38 (47.6%) patients had left-sided stroke, while 33 (41.2%) patients had right-sided stroke. Bilateral involvement was seen in 9 (11.2%) of patients. Left Middle Cerebral Artery (MCA) was the most commonly involved vessel in ischaemic stroke 32 (40%), followed by right MCA 20 (25%) [Table/Fig-2].

Age group (in years)	No. of patients (n)		Total
	Male	Female	
≤40	3	1	04 (5%)
41-50	9	3	12 (15%)
51-60	16	6	22 (27.5%)
61-70	23	7	30 (37.5%)
71-80	8	4	12 (15%)
Total	59 (73.7%)	21 (26.3%)	80 (100%)

[Table/Fig-1]: Distribution of cases according to demographic characterstics.

CT findings	No. of patients (n)	Percentage (%)
Right MCA infarct	20	25
Left MCA infarct	32	40
Lacunar infarct	21	26.2
Right ACA infarct	10	12.5
Left ACA infarct	16	20
Cerebellar infarct	2	0.25

[Table/Fig-2]: Distribution of cases according to CT findings.

Hypertension was the most common risk factor i.e., 57 (71.1%). Increased carotid Intimal Medial Thickness (IMT) was seen in 62 (77.5%) of stroke patients. The most significant risk factor for increased intimal thickness was found to be hypertension 51 (89.5%) (p-value=0.05) [Table/Fig-3].

Risk factor	No. of patients	No. of patients with significant stenosis	Patients with increased CIMT >0.7 mm	p-value
Hypertenssion	57 (71.1%)	16 (100%)	51 (89.5%)	0.000054
Diabetes mellitus	19 (23.7%)	09 (56.7%)	16 (86.1%)	0.042
Smoking	45 (56.5%)	14 (87.5%)	40 (89.4%)	0.0056
Dyslipidaemia	36 (45.4%)	15 (93.2%)	30 (83.3%)	0.025

[Table/Fig-3]: Distribution of cases according to risk factors.

A total of 54 (67%) stroke patients were found to have a plaque in their carotid vasculature. Out of the patients, who had carotid plaque, 25 (46.3%) had bilateral involvement and 29 (53.7%) had unilateral involvement. In patients showing unilateral involvement, left-sided involvement 19 (35.2%) was more common than the right-side 10 (18.5%). In the present study, the carotid bulb 23 (42.5%) was the most common site for plaque formation. In the present study, out of 54 (67%) of patients who had plaque, majority of patients 38 (47.5%) had <50% stenosis and 16 (20%) of patients had significant stenosis (>50%). Out of all the patients, who were found to have significant stenosis, the most common age group was 61-70 years 06 (37.5%), the most commonly affected side was the left side 08 (50%) and the most common site involved was the carotid bulb 08 (50%) [Table/Fig-4,5].

Plaque distribution	Right	Left	Bilateral	Total no. of patients
Common Carotid Artery (CCA)	02 (3.7%)	5 (9.2%)	10 (18.5%)	17 (31.4%)
Internal Carotid Artery (ICA)	05 (9.2%)	7 (12.9%)	2 (3.7%)	14 (25.1%)
Carotid bulb	03 (5.5%)	7 (12.9%)	13 (24.07%)	23 (42.5%)
Total	10 (18.5%)	19 (35.1%)	25 (46.3%)	54 (100%)
Distribution in significant stenosis (>50%)				
Common Carotid Artery (CCA)	1 (6.2%)	2 (12.5%)	0 (00%)	3 (18.75%)
Internal Carotid Artery (ICA)	2 (12.5%)	2 (12.5%)	1 (6.2%)	5 (31.25%)
Carotid bulb	2 (12.5%)	4 (25%)	2 (12.5%)	8 (50%)
Total	5 (31.2%)	8 (50%)	3 (18.8%)	16 (100%)

[Table/Fig-4]: Distribution of plaque according to side and vessel involved.

Percentage stenosis	No. of patients (male)	No. of patients (female)	Total no. of patients
Normal	17	9	26 (32.1%)
1-49%	31	07	38 (47.5%)
50-69%	06	03	09 (11.2%)
70-89%	04	02	06 (7.5%)
90-99%	01	0	01 (1.2%)
Total	59 (73.7%)	21 (26.2%)	80 (100%)

[Table/Fig-5]: Distribution of cases according to degree of stenosis.

In the present study, 21 (38.8%) of patients had Type 3 plaque. Out of 54 patients who had plaque, 20 (37.23%) patients had plaque with an irregular margin [Table/Fig-6]. The author found that 48.7% of the ICAs showed PSV ≤125 cm/sec and 21.5% of the ICAs showed PSV >230 cm/sec. In the present study, a total of 160 vessels were evaluated for PSV ICA/CCA ratios. About 13.1% of vessels had PSV ICA/CCA ratio of >4 [Table/Fig-7].

Type of plaque	Smooth margin	Irregular margin	Ulceration	Haemorrhage	No. of patients
Type 1	2	3	3	6	14 (25.9%)
Type 2	1	2	4	4	11 (20.3%)
Type 3	6	10	2	3	21 (38.8%)
Type 4	3	5	0	0	08 (14.8%)
Total	12 (22%)	20 (37.2%)	9 (16.6%)	13 (24%)	54

[Table/Fig-6]: Distribution of cases according to plaque characterisation.

A. Distribution of vessels according to ICA PSV			
	Total no. of vessels (160)		
ICA PSV (CM/SEC)	Right	Left	n (%)
<125	48	30	78 (48.7%)
125-230	20	28	48 (30%)
>230	12	22	34 (21.5%)
B. Distribution of vessels according to PSV ICA/CCA ratio			
	Total no. of vessels (160)		
PSV ICA/CCA	Right	Left	n (%)
<2	59	44	103 (64.3%)
2-4	12	24	36 (22.5%)
>4	09	12	21 (13.1%)
Total	80	80	100%

[Table/Fig-7]: Distribution of vessels according to Doppler finding.

Out of the total 6 patients with >70% stenosis, five patients had ICA PSV >230 and out of 154 patients with <70% stenosis, 125 patients had ICA PSV ≤230. Hence, ICA PSV >230 cm/sec had sensitivity of 83.3% and specificity of 81.1% for >70% stenosis [Table/Fig-8].

PSV ICA (cm/sec)	>70% stenosis	<70% stenosis	Total
>230	5	29	34
≤230	1	125	126
Total	6	154	160

[Table/Fig-8]: Senstivity and specificity according to ICA PSV for >70% stenosis values presented in percentages.

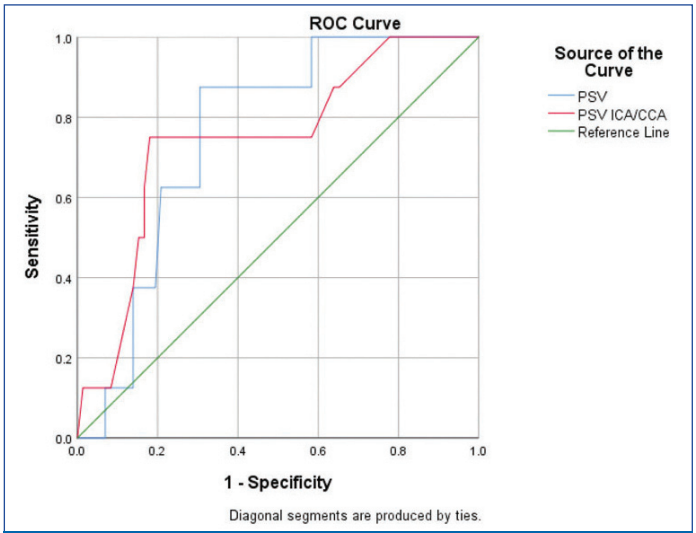
Out of the 6 patients with >70% stenosis, four patients had PSV ICA/CCA ratio >4 and out of 154 patients with stenosis <70%, 137 patients had PSV ICA/CCA ratio ≤4. Hence, PSV ICA/CCA of ratio >4 had the sensitivity of 66.6% and specificity of 88.9% for >70% stenosis [Table/Fig-9].

ICA PSV >230 cm/sec had sensitivity of 83.3% and specificity of 81.1% for >70% stenosis. Area under the curve was 0.75. PSV ICA/CCA of ratio >4 had the sensitivity of 66.6% and specificity of 88.9% for >70% stenosis. Area under the curve was 0.74 [Table/Fig-10].

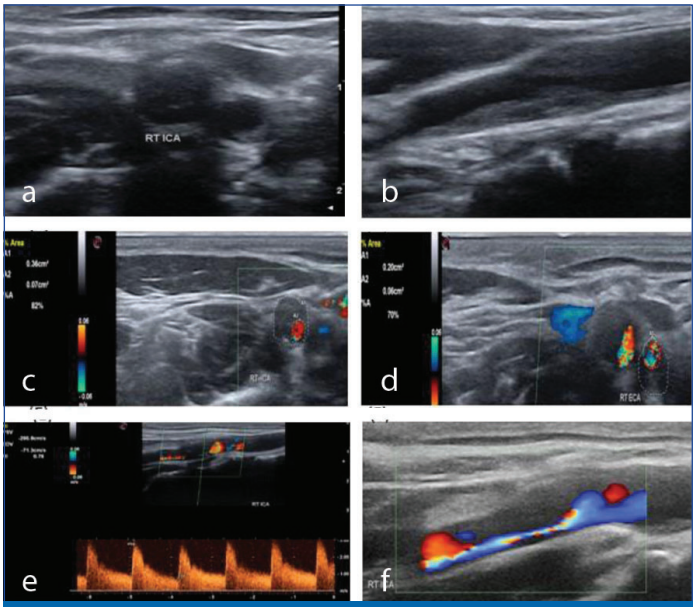
[Table/Fig-11,12] shows the ultrasound and colour Doppler imaging for different patients.

PSV ICA/CCA	>70 stenosis	<70% stenosis	Total
>4	4	17	21 (13.1%)
≤4	2	137	139 (86.9%)
Total	6	154	160 (100%)

[Table/Fig-9]: Senstivity and specificity according to PSV ICA/CCA for >70% stenosis values presented in percentages.



[Table/Fig-10]: Receiver operating characteristic curve (ROC) graph demonstrating the sensitivity and specificity of PSV >230 and PSV ICA/CCA ratio >4 for detecting >70% stenosis.

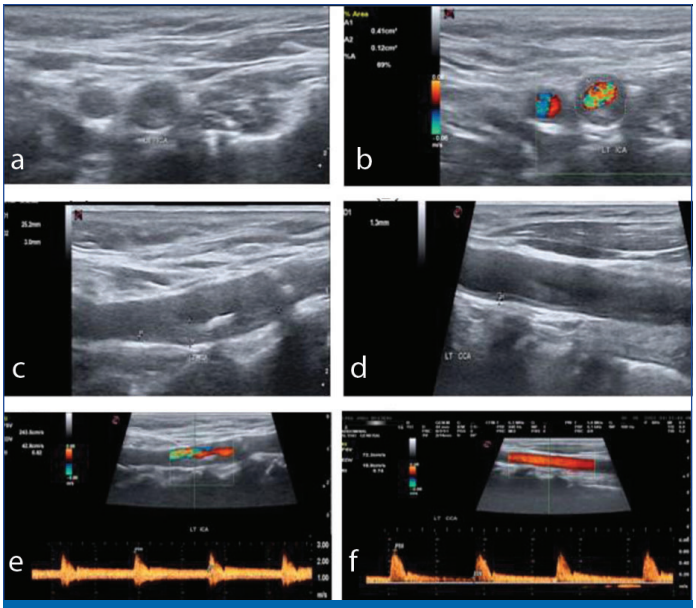


[Table/Fig-11]: (a) 72-year-old male patient with left-sided hemiparaesis (b) Mode ultrasound shows Type 2 plaque in RT ICA with 82% stenosis, Type 1 plaque in RT ECA with 70% stenosis, and RT carotid bulb plaque with intraplaque haemorrhage (a,b,c,d). On colour Doppler imaging, RT ICA PSV was 294 cm/sec and PSV ICA/CCA was 6.1 (e and f).

DISCUSSION

In present study, out of 80 patients 73.7% patients were males and 26.3% were females. This male preponderance is assumed to be brought on by differences between men and women's carotid bifurcation architecture and sex hormone levels. Women have a larger ICA than men, and in comparison to the inflow area, women have a larger outflow area. In addition, oestrogens are thought to have a role in the suppression of stroke risk factor pathology [8].

In the present study, out of the 80 patients, 47.6% patients had left-sided stroke. Possible explanation for the left-sided predominance could be due to higher propensity for formation of vulnerable plaque including the intraplaque haemorrhage on left



[Table/Fig-12]: (a) 55-year-old male stroke patient with right hemiparaesis. (b) Mode ultrasound showed Type 3 plaque in left ICA with 69% stenosis (a, b and c). Left Common carotid intimal thickness was 1.3 mm (d) On colour Doppler imaging, left ICA PSV was 243 cm/sec and PSV ICA/CCA was 3.3 (e and f).

side [9]. This was in accordance with the study done by Chitrah R et al., (64.5%) [1]. In present study, the authors also found that left MCA was the most commonly involved vessel in ischaemic stroke (40%). This could be justified by the fact that, due to the size of the territory and the direct flow from the ICA into the MCA, providing the easiest path for thromboembolism. This was in accordance with the study done by Chitrah R et al., (26.6%) [1].

The present results showed that the chance of carotid artery involvement increased significantly when multiple risk factors were involved and authors found in the present study that hypertension was the commonest risk factor for stroke (71.1%). This was in accordance to the study done by Khedr E et al., (74.8%) and Dhamija RK and Donnan GA, (69%) [10,11]. In the present study, 67% stroke patients were found to have plaque in their carotid vasculature, which was in concordance with the study conducted by Sarkar A et al., (2018) (74%), while study conducted by Bollipo JP and Rao PB found atherosclerotic plaque in 82% of patients this could be explained by the fact that majority of study population in his study was of >61 year (59%) as compared to the present study which was only 42% [12,13].

Out of the patients who had unilateral carotid plaque involvement, left-sided involvement (35.2%) was more common than the right-side (18.5%). Predilection for left-sided involvement was justified by a study done by Hernández SAR et al., [14]. He proposed that it could be due to haemodynamic effects related to the specific anatomy of the carotid vessels. The left CCA is directly originates to the aortic arch and runs more in an even line with the ascending aorta while the right CCA originates from the brachiocephalic trunk. Thus, the mean flow velocity was significantly higher in the left than in the right carotid artery, leading to greater haemodynamic stress and intimal damage in the left carotid artery. A study conducted by Patel AP et al., also showed that 48% of the patients had B/L involvement, while Khattak MI et al., found bilateral involvement in only 27.4% of the patients [15,16].

In the present study, the carotid bulb (42.5%) was the most common site for plaque formation, followed by the CCA (31.4%) and the ICA (25.1%). Fisher M and Fieman S suggested that plaque formation is thought to originate from endothelial damage caused by disturbances in local blood flow, which are influenced by bifurcation anatomy [17]. Low ratios (i.e., a relatively small outflow to inflow area) result in loss of flow energy, increasing local stress and endothelial damage due to increasing reflection of the pulse wave [8]. Similar results were also found in the studies of Haque MN et al., (32.3%) and Gyawali M et al., (49.3%) [18,19].

In the present study, 38.8% of patients had type 3 plaque followed by type 1 plaque (25.9%). Type 4 was the least common (14.8%). Plaque ulceration was found to be most common in type 2 plaque (36.3%). This was in accordance with Gyawali M et al., (48%) and Chamarthi M et al., 34 (31%) who also found the type 3 plaque most commonly in their studies [19,20].

The present study showed a PSV of >230 cm/s for >70% stenosis had a sensitivity of 83.3% and specificity of 81%. (p-value <0.05). We also found that majority of patients had an increased ICA PSV (>125 cm/sec) on the left side which could be justified by the fact that the right CCA arises from the brachiocephalic trunk, whereas the left CCA stems directly from the aortic arch and runs more in an even line with the ascending aorta. Thus, the mean flow velocity was significantly higher in the left than in the right carotid artery. Measuring PSV is the most important component of the carotid artery Doppler examination. As a function of the area of the residual lumen, PSV increases with the narrowing of the artery, implying its usefulness for grading the carotid artery stenosis [21]. This was in concordance with the study done by Gornik HL et al., who showed a PSV of >230 cm/s for >70% of stenosis had a sensitivity of 93.9% and specificity of 78.2% [22].

Strength of the present study are that it can help in plaque characterisation and morphology. Duplex sonography combining high-resolution imaging and Doppler spectrum analysis is easily available, non invasive, accurate, and cost-effective means of detecting and assessing carotid arterial disease.

Limitation(s)

Only limitation of present study was that, it did not compare with any other gold standard modality.

CONCLUSION(S)

The carotid bulb was the most often affected region, and the main causal lesion was atherosclerotic plaque in the extra cranial carotid artery. Vascular stenosis was present at various levels, from near occlusion to entire occlusion. When it came to identifying high grade stenosis and separating total occlusion from near total occlusion, colour Doppler imaging outperformed B mode imaging. Characterisation of plaques enhances the understanding of natural history and ultimately, the treatment of atherosclerotic disease and it is useful in the assessment of vulnerability of atherosclerotic lesion.

REFERENCES

[1] Chitrah R, Sivaranjinie S, Padmareka D, Umamageswari A, Elamparidhi P, Sibhithran R. Correlation of carotid artery doppler with risk factors and computed tomography brain in patients with ischemic cerebrovascular accident. Int J Anatomy Radiol Surg. 2019;8(3):RO15-RO20.
[2] Balami JS, Chen RL, Grunwald IQ, Buchan AM. Neurological complications of acute ischaemic stroke. The Lancet Neurology. 2011;10(4):357-71.
[3] Inzitari D, Eliasziw M, Gates P, Sharpe BL, Chan RK, Meldrum HE, et al. The causes and risk of stroke in patients with asymptomatic internal-carotid-artery stenosis. New England Journal of Medicine. 2000;342(23):1693-701.
[4] U-King-Im JM, Young V, Gillard JH. Carotid-artery imaging in the diagnosis and management of patients at risk of stroke. The Lancet Neurology. 2009;8(6):569-80.
[5] Yusof NN, McCann A, Little PJ, Ta HT. Non invasive imaging techniques for the differentiation of acute and chronic thrombosis. Thrombosis Research. 2019;177:161-71.
[6] Gray-Weale AC, Graham JC, Burnett JR, Byrne K, Lusby RJ. Carotid artery atheroma: Comparison of preoperative B-mode ultrasound appearance with carotid endarterectomy specimen pathology. J Cardiovasc Surg. 1988;29:676-81.
[7] Grant EG, Benson CB, Moneta GL, Alexandrov AV, Baker JD, Bluth EI, et al. Carotid artery stenosis: Gray-scale and Doppler US Diagnosis-Society of Radiologists in Ultrasound Consensus Conference. Radiology. 2003;229(2):340-46.
[8] Schulz UG, Rothwell PM. Sex differences in carotid bifurcation anatomy and the distribution of atherosclerotic plaque. Stroke. 2001;32(7):1525-31.
[9] Larson AS, Brinjikji W, Savastano L, Scharf E, Huston III J, Benson JC. Left sided carotid arteries have a higher prevalence of intraplaque hemorrhage than right-sided: An asymmetric conundrum. The Neuroradiology Journal. 2020;33(6):494-500.

[10] Khedr E, Tony AA, Habeel M, Nasreldein A. Frequency and risk factors of carotid artery disease among ischemic stroke patients in the south Egypt: Hospital-based study. Egypt J Neurol Psychiatry Neurosurg. 2021;57:128. https://doi.org/10.1186/s41983-021-00382-5.
[11] Dhamija RK, Donnan GA. The role of neuroimaging in acute stroke. Ann Indian Acad Neurol. 2008;11(Suppl S1):12-23.
[12] Sarkar A, Haque F, Sengupta RS, Ghosh A, Chakraborty S, Mondal TK, et al. Impact of atherosclerotic carotid artery disease in patients of stroke and recent TIA using colour doppler sonography-a prospective study in Eastern India. International Journal of Contemporary Medical Research. 2018;5(4):D1-D4.
[13] Bollipo JP, Rao PB. Colour doppler assessment of extra cranial carotid arteries in carotid artery disease with correlation of risk factors in predicting cerebro vascular accident in patients with carotid atheromatous disease. International Journal of Advances in Medicine. 2018;5(6):1402-06. ISSN 2349-3933.
[14] Hernández SAR, Kroon AA, van Boxtel MPJ, Mess WH, Lodder J, Jolles J, et al. Is there a side predilection for cerebrovascular disease? Hypertension. 2003;42:56-60.
[15] Patel AP, Wang M, Kartoun U, Kenney Ng, Khera AV. Quantifying and understanding the higher risk of atherosclerotic cardiovascular disease among south Asian individuals Circulation. 2021;144:410-22. https://doi.org/10.1161/CIRCULATIONAHA.120.052430.
[16] Khattak MI, Khan F, Fida Z, Zar A. Carotid artery stenosis; in ischemic stroke patients. Professional Med J. 2017;24(8):1126-31. Doi: 10.17957/TPMJ/17.4064.
[17] Fisher M, Fieman S. Geometric factors of the bifurcation in carotid atherogenesis. Stroke. 1990;21(2):267-71.
[18] Haque MN, Azam MS, Sarwar MG. Status of carotid artery atherosclerosis among the ischemic stroke patients. Med Res Chronicles [Internet]. 2022 Apr 30 [cited 2022 Sep 3];9(2):152-57.
[19] Gyawali M, Sharma P, Karki D. Study of carotid doppler in patients with ischemic stroke. Journal of Brain and Spine Foundation Nepal. 2021;2(1):24-30.
[20] Chamarthi M, Lava Kumar B, Nirusha R, Pravallika I, Kejriwal GS. Colour doppler evaluation of carotid arteries in stroke patients: A study conducted in a rural tertiary care medical college hospital in South India. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS). 2017;16(1):04-09.
[21] Alexandrov AV, Brodie DS, McLean A, Hamilton P, Murphy J, Burns PN. Correlation of peak systolic velocity and angiographic measurement of carotid stenosis revisited. Stroke. 1997;28(2):339-42.
[22] Gornik HL, Rundek T, Gardener H, Benenati JF, Dahiya N, Hamburg NM. Optimization of duplex velocity criteria for diagnosis of internal carotid artery (ICA) stenosis: A report of the Intersocietal Accreditation Commission (IAC) Vascular Testing Division Carotid Diagnostic Criteria Committee. Vascular Medicine. 2021;26(5):515-25. Doi: 10.1177/1358863X21101125.

PARTICULARS OF CONTRIBUTORS:
1. Professor, Department of Radiodiagnosis, MGM Medical College, Indore, Madhya Pradesh, India.
2. Assistant Professor, Department of Radiodiagnosis, MGM Medical College, Indore, Madhya Pradesh, India.
3. Postgraduate Resident, Department of Radiodiagnosis, MGM Medical College, Indore, Madhya Pradesh, India.
4. Postgraduate Resident, Department of Radiodiagnosis, MGM Medical College, Indore, Madhya Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Vasudev Lodhi,
Postgraduate Resident, Department of Radiodiagnosis, MGM Medical College, Indore, Madhya Pradesh, India.
E-mail: drvasu.dev05@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jan 03, 2023
- Manual Googling: Feb 16, 2023
- iThenticate Software: Mar 08, 2023 (11%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval Obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Jan 02, 2023**
Date of Peer Review: **Feb 01, 2023**
Date of Acceptance: **Mar 09, 2023**
Date of Publishing: **May 01, 2023**