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CODEN: IJBABN **Original Research Article**

Correlation of neurological dysfunction with MRI brain findings and carotid Doppler study in acute ischemic stroke

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Abstract

Background: Stroke is defined as an abrupt onset of neurologic deficit due to vascular cause. It is one of the leading causes of mortality and morbidity all over the world. Lesions of extra cranial carotid arteries are implicated in majority of cases of acute ischemic stroke. Carotid Doppler is a non-invasive imaging technique, with sensitivity approaching that of angiography**.**
Aims and Objectives: To find out correlation of carotid artery Doppler findings with MRI brain findings in clinically suspected acute ischemic stroke patients.
Materials and Methods: This is a hospital based prospective cross sectional study of sample size 100 subjects. The study population include patients referred to the Department of Radio-Diagnosis with clinically suspected stroke for color Doppler study of bilateral carotid artery within 7 days of onset of symptoms, underwent bilateral carotid artery color Doppler study, subsequently MRI brain scans were performed on 1.5T MRI machine. Study includes patients in duration of October 2018 to July 2020.
Results: Carotid stenosis is one of the common causes of ischemic stroke. Carotid Doppler findings are positive in 56.9% cases detected on MRI in MCA territory & right side was affected more than the left side. The prevalence of carotid stenosis increases with increase in age. Carotid stenosis is more commonly seen in male gender. Carotid artery stenosis is associated with risk factors like diabetes mellitus, hypertension, smoking & hyperlipidemia.
Conclusion: The present analysis showed that mean age was 55.97 years; mean NIHSS score was 8.36 and stroke (infarct) was more common in males in the age group of 60-69 years. Most common risk factor associated with stroke (infarct) was hypertension followed by tobacco chewing and diabetes. Sensitivity of predicting stroke by carotid Doppler is 56.9%.
Keywords: Stroke, Carotid Color Doppler, Magnetic Resonance Imaging.

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1. Introduction

Stroke is a condition caused due to insufficient supply of blood (lack of oxygen) to the brain cells which damages them and may result in their death. Blood flow may be interrupted due to clot in the blood vessel that disrupts the supply. It results in abrupt loss of central nervous system function by disrupting the blood supply to the brain. Annually, there are nearly 800000 strokes in the United States and 15 million strokes worldwide. It is one of the leading causes of physical disability in developed countries, and is major killer after heart attack. Important risk factors that are associated with stroke are hyperlipidemia, hypertension, diabetes and smoking (tobacco chewing). Important points considered in stroke management are to prevent brain damage, prevent recurrence, prevent complications and optimize recovery.

The two processes that give rise to stroke are blockage of arteries, causing cerebral ischemia or infarction and rupture of arteries, causing intraparenchymal

hemorrhage. Hemorrhage is associated with higher mortality rates because it is more destructive and dangerous than ischemic stroke. Ischemic stroke are more common (85%) then hemorrhagic stroke and can be classified into embolic and thrombotic categories.

Severe stenosis of internal carotid artery is correlated for predicting cardiovascular ischemic events [1]. Thrombosis or plaque of the extracranial carotid arteries are one of the important risk factor for development of stroke [2]. Thrombosis and plaque of carotid arteries of same side is an important cause of anterior circulation stroke [3]. Atherosclerotic disease of the extracranial carotid arteries has long been recognized as the frequent source of emboli that travel to the brain causing stroke [4].

For evaluation of extracranial carotid arteries, Doppler is non invasive imaging modality, widely available with sensitivity near to that of angiography.

1.1 Diagnosis of Stroke

Carotid artery evaluation for occlusive diseases may be possible non-invasively through Magnetic resonance angiography and ultrasound color doppler examinations of the carotid arteries. Carotid doppler is a screening procedure which is simple and non invasive that have profound diagnostic and therapeutic role in predicting and preventing a potentially lethal and serious consequences of stroke. NCCT head is primary modality for identification of suspected stroke in the initial stages. In the first 6 hours from the onset of the stroke, the CT scan fails to capture the early ischemic changes in most cases. Primary role of NCCT head is to rule out any intraparenchymal bleed. MRI brain is more sensitive to ischemic changes as compared to NCCT head.

1.1.1 *Carotid Doppler*

Carotid Doppler is accurate means of identifying carotid artery stenosis and is important tool in stroke prevention [5]. Color flow imaging and Power Doppler mode are used to identify complete occlusion. Hypoechoic plaque are best identified with color flow imaging then B-mode scanning. Analysis of spectral waveform at the site of maximum stenosis was done and degree of stenosis is calculated. PSV, ICA/CCA PSV ratio and ICA EDV was measured. Carotid occlusion was diagnosed by occlusion of lumen by echogenic material, absence of arterial pulsations, , absence of signals of doppler flow, increased ICA/CCA PSV ratio, increased EDV, area of stenosis and increased Carotid intima media thickness. Grayscale ultrasound can be used for measuring the intima-media thickness, which is very good marker for atherosclerosis [5,6]. Carotid intima-media thickness greater than 0.8mm was considered abnormal [7,8].

1.1.2 *Standard MRI*

Cytotoxic edema representing early ischemic changes (acute stroke) are detected by DWI sequence of MRI. Vasogenic edema is detected by T1WI and T2WI images that is seen in subacute phase of stroke and is seen after 24 hours to several days. Diffusion FLAIR mismatch can be used to detect penumbra. MRI with diffusion weighted images are considered as gold standard in acute stroke imaging. DWI sequence of MRI non invasively detects ischemic changes within minutes of stroke onset.

ASPECT SCORE: Alberta stroke program Early CT score is a quantitative 10 point topographic score. For nullifying inter-observer variability of radiologist and for easy reproducibility grading system for reporting Infarcts, Alberta stroke program Early CT score was developed. Same Aspect score is also applicable in MRI. For calculating ASPECT score two regions are evaluated one at capsulo-ganglionic region and another at ventricular level involving centrum semiovale and corona radiata (supra ganglionic level). To calculate the ASPECT score, each region involved will get -1 score, so total score is calculated by substracting score for each region involved. No region involvement will give a score of 10 and if all regions are involved total ASPECT score will be 0.

For evaluation of stroke patient neurological examination (NIHSS)[9], in-vivo imaging techniques such as Carotid Doppler, Non Contrast Computed Tomography (CT) head and Magnetic Resonance Imaging (MRI) brain are essential for diagnosis and treatment with thrombolytic therapy[10].

1.2 Pathophysiology

The blood supply to the anterior parts of the brain comes from the two carotid arteries, which give rise to the internal carotid arteries, these again give rise to the anterior and middle cerebral arteries. The basilar artery formed by two vertebral arteries which give rise to posterior cerebral artery which is supplying the posterior aspect of brain, thalami, mid brain and pons.

The CCA is divided into the internal and external carotids at the C4-5 level in 50% of the patients. In approximately 40% of patients, the bifurcation is higher, and it is lower in the remaining 10%. The circle of Willis provides collateral flow between the left and right hemispheres of the brain and connects the anterior and posterior circulation. Reduction in the flow of blood to any part of the brain first causes ischemia, reversible loss of function and then, if reduction is severe or prolonged, infarction with irreversible cell death. Plaque or thrombus of the internal carotid artery near the bifurcation is the most importance cause of stroke[11].

Clinical evaluation of stroke patient is done by NIH stroke scale, that was built to assess the cognitive effects of stroke. Quantitative assessment of stroke related neurologic dysfunction is possible with NIHS scale. It maintains uniformity between all people involved in stroke patient's treatment. Stroke severity assessment and its prognosis can be assessed with NIHS scale. Stroke occurring within 6 hours is considered as hyperacute stroke and within 7 days is considered as acute stroke.

1.3 Stroke Complications

Hemorrhagic transformation and malignant edema are the most dreadful complications of ischemic stroke [12,13]. Hemorrhagic transformation is more common than malignant edema[14-16].

1.4 Treatment

Thrombolysis by using recombinant tissue plasminogen activator (rtPA) involves rapid recanalization of the blocked artery and increases the possibility of good neurological outcome in acute ischemic stroke [17]. Therapeutic removal of clot can be achieved by dissolving the thrombus using clot busting drugs (thrombolysis) or mechanically (thrombectomy). Thrombectomy is the removal of blood clots in the Carotid and cerebral arteries by interventional endovascular neuroradiological methods.

1.5 Aims and Objective:

To find out correlation of carotid artery Doppler findings with MRI brain findings in acute ischemic stroke patients.

2. Materials & Methods

This is a hospital based prospective cross sectional study of sample size of 100 patients. The study was approved by ethical committee of institution (ethical committee approval letter -36113-15/MC/IEC/2018). The study includes patients referred to the department of radio-diagnosis with clinically suspected stroke for color Doppler study of bilateral carotid artery within 7 days of onset of symptoms, underwent bilateral carotid artery color Doppler study on MINDRAY ultrasound and color doppler machine, subsequently MRI scans were performed on 1.5 Tesla HITACHI MRI machine. Study includes patients in duration of October 2018 to July 2020. Complete evaluation of all patients was done, includes their history of risk factors (tobacco chewing, hypertension, ischemic heart disease, smoking, diabetes), clinical evaluation as per NIHSS format, Carotid color Doppler reporting as per color doppler format and MRI brain reporting as per ASPECT scale. Data is collected, systematic analysis of data was done and statistical test applied.

2.1 Statistical test

Descriptive statistical analyses were carried out with Statistical Package for Social Sciences (SPSS Complex Samples) Version 21.0 for windows. Results on continuous measurements are presented as Mean ± SEM and results on categorical measurements are presented in Number (%). Significance is assessed at a level of 1%. Correlation of data done by using Pearson correlation coefficient, scatter graph was generated and r value was calculated using p value <0.01.

3. Results

All statistical calculations was done by SPSS software applying Pearson correlation coefficient, scatter graph was generated and r value was calculated using p value <0.01. In the duration of this study, total of 100 patients with ischemic stroke were evaluated by carotid Doppler and DWI sequence of MRI within 7 days of stroke onset. The present analysis showed that mean age was 55.97 years; mean NIHSS score was 8.36 and stroke (infarct) was more common in males [Table 2] in the age group of 60-69 years [Table 1].

Table 1: Age group distribution of cases

Age	Male	Female	Total
Below 30	1	2	3
Between 30 to 39	5	5	10
Between 40 to 49	13	2	15
Between 50 to 59	17	7	24
Between 60 to 69	23	12	35
Above 70	7	6	13
Total	66	34	100

Table 2: Gender distribution of cases

Male	Female
66	34

Most common risk factor associated with stroke (infarct) was hypertension followed by tobacco chewing and diabetes [Table 3].

Table 3: Risk Factor distribution of cases

Risk factor	Male	Percentage (%)	Female	Percentage (%)	Total	Percentage (%)
Smoking	20	29.4	0	0	20	20
Diabetes	11	16.1	13	25	24	24
Hypertension	19	27.9	20	38.4	39	39
Ischaemic heart disease	6	8.8	3	5.7	9	9
Tobacco chewing	12	17.6	16	30.7	28	28

Table 4: NIHSS score distribution of cases

NIHSS Score	Frequency
Between 1 to 5	28
Between 6 to 10	35
Between 11 to 15	27
Between 16 to 20	10

Carotid Doppler findings were correlated with infarct detected by DWI sequence of MRI in MCA territory [Figure 1].

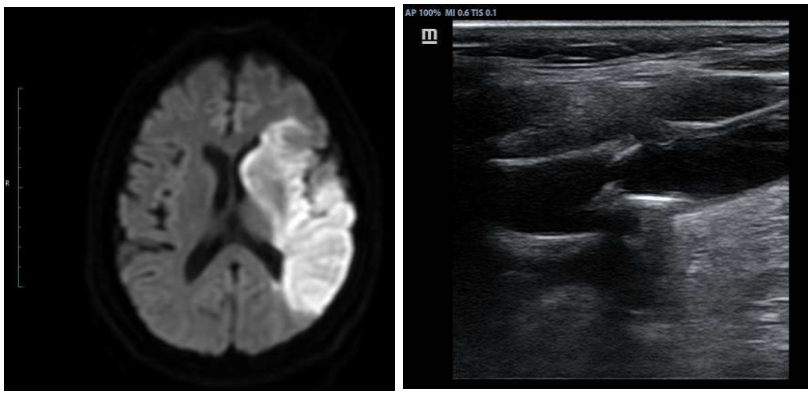

Figure 1: MRI-DWI image shows restriction in left caudate nucleus, internal capsule, M1, M2 & M3 in MCA artery distribution in a patient presenting with hemiparesis

In a same patient longitudinal grey scale ultrasound images of left carotid artery shows echogenic plaque giving posterior acoustic shadowing noted in left CCA and causing significant stenosis.

Carotid doppler findings were correlated with infarct diagnosed by DWI sequence of MRI [Figure 2, 3, 4 & 5]. Most frequent NIHSS score is between 6 to 10.

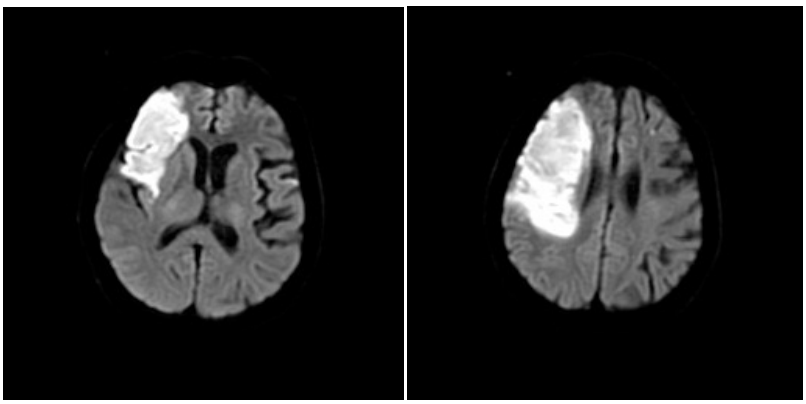

Figure 2: MRI-DWI brain image shows restriction in M1, M2, M4 and M5 area as per ASPECT distribution in MCA artery distribution in a patient of hemiparesis

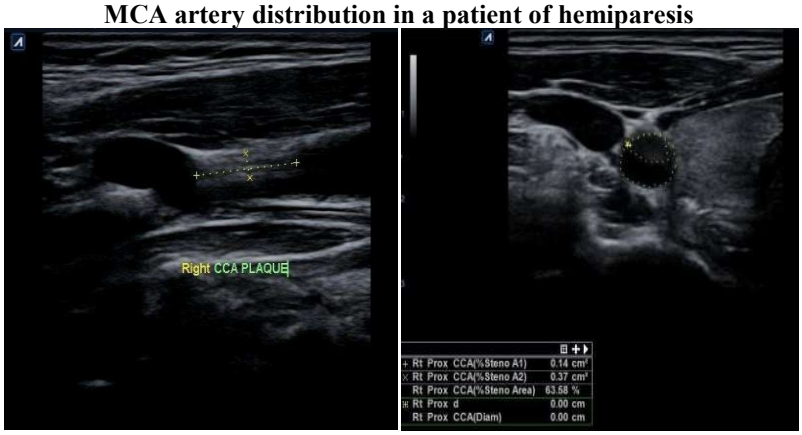

Figure 3: In same patient Longitudinal and transverse grey scale ultrasound images of right carotid artery shows hyperechoic plaque in right CCA causing significant 63 % stenosis

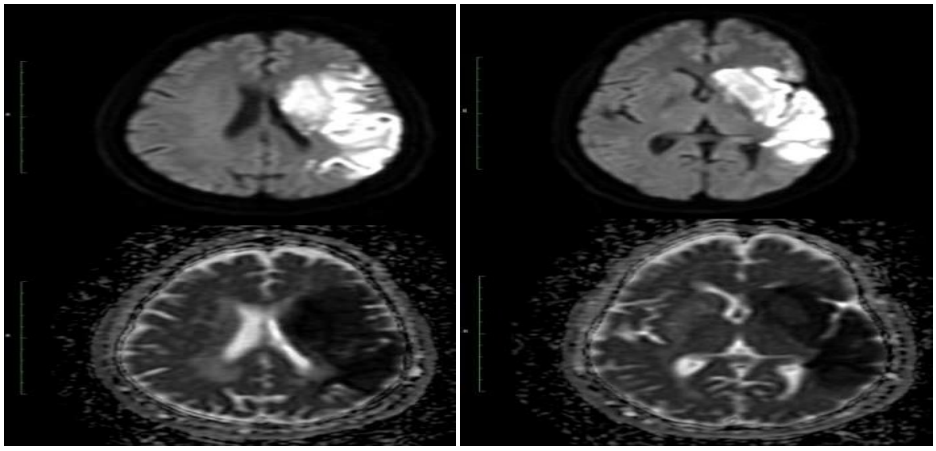

Figure 4: MRI-DWI ADC image shows restriction in left caudate nucleus, left internal capsule, M1,M2,M3,M4 & M5 with corresponding reduced diffusivity in ADC map in MCA artery distribution in a patient who presented with right hemiparesis

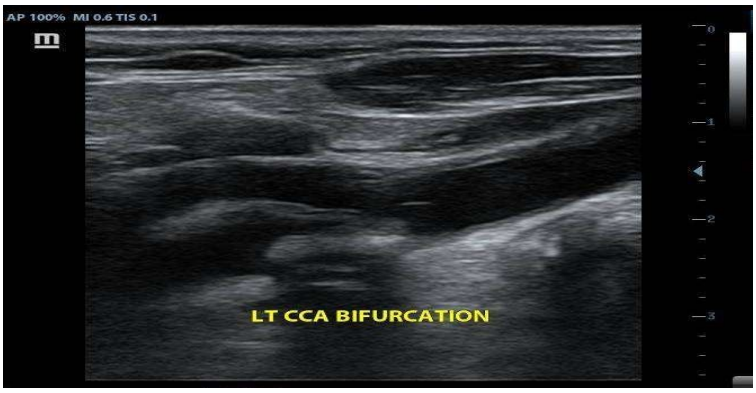

Figure 5: In same patient Longitudinal grey scale ultrasound images of left carotid artery shows echogenic plaque giving posterior acoustic shadowing noted in left ICA and causing significant stenosis

In carotid Doppler most common artery affected was common carotid artery. The plaques were classified according to their anatomical location. The right side was affected more than the left side. Most common MRI, DWI, MCA ASPECT score is between 4 to 7 [Table 5]. Infarct is seen most commonly in MCA territory in 70.4 % cases.

Table 5: MRI, MCA, ASPECT score distribution of cases

S. No.	MRI, MCA, ASPECT	Frequency
1	Between 0 to3	07
2	Between 4 to 7	37
3	Between 8 to 9	22
4	10	34

Pearson correlation coefficient for PSV of right and left internal carotid artery with MRI, DWI, MCA, ASPECT score is -0.455 and -0.517 respectively. It suggest negative correlation of PSV of internal carotid artery with MRI, DWI, MCA, ASPECT score, finding suggesting increase in PSV of internal carotid artery will show decrease in ASPECT score. Pearson correlation coefficient for grey scale ultrasound of right and left carotid artery [Table 6] with MRI, DWI, MCA, ASPECT score is -0.438 and -0.450 respectively. It suggest negative correlation of grey scale ultrasound with MRI, DWI, MCA and NCCT, ASPECT score, finding suggesting increase in plaque will show decrease in ASPECT score.

Table 6: Grey Scale USG findings in Carotid Duplex scan in right carotid artery

Grey scale USG findings	Right carotid artery	Left carotid artery
No plaque	80(80 %)	83(83%)
Plaque in CCA	13(13 %)	12(12 %)
Plaque in ICA & CCA	07(07 %)	05(05 %)

Pearson correlation coefficient for percentage of stenosis of right and left carotid artery [Table 7] with MRI, DWI, MCA score is -0.465 and -0.462 respectively. It shows negative correlation of percentage stenosis of carotid artery with MRI DWI MCA ASPECT score, finding suggesting increase in grade of stenosis of carotid artery will show decrease in ASPECT score.

Table 7: Percentage Area of Grading of Stenosis in Carotid Duplex scan

Percentage area of grading of stenosis	Right carotid artery	Left carotid artery
No stenosis	80(80%)	83(83 %)
<50% Stenosis	13(13 %)	09 (09 %)
50-69% Stenosis	05(05 %)	08(08 %)
>70 % Stenosis	02(02 %)	00(00 %)

Pearson correlation coefficient for CIMT of right and left carotid artery [Table 8] with MRI, DWI, MCA, ASPECT score is -0.285 and -0.321 respectively. It suggest negative correlation of CIMT of carotid artery with MRI, DWI, MCA, finding suggesting increase in CIMT of carotid artery will show decrease in ASPECT score.

Table 8: CIMT in Grey Scale USG findings in Carotid Duplex scan in right carotid artery

CIMT	Right carotid artery	Left carotid artery
Less than or equal to 0.8	79(79%)	86(86%)
More than 0.8	21(21%)	14(14%)

Carotid stenosis is one of the common causes of ischemic stroke. Carotid Doppler findings is positive in 37 % & right side was affected more than the left side.

MRI shows infarct in MCA territory in 65 % cases [Table 9] considering DWI MRI sequence as gold standard. 56.9% cases of MCA territory stroke shows correlation with carotid doppler findings. Our study shows that sensitivity of predicting stroke by carotid doppler is 56.9 %. The prevalence of carotid stenosis increases with increase in age. Carotid artery stenosis is seen in both male and female with male predominance and associated with risk factors like smoking, diabetes mellitus & hypertension.

Table 9: MRI brain findings

MRI brain findings in MCA Territory	Number
Normal	35(35%)
Infarct	65(65%)

Doppler sonography of the carotid arteries is simple and non invasive test which can predict and prevent a potentially fatal and devastating stroke. Percentage grading of stenosis increases with increase in age and is more common in men than women. Prevalence of mild to moderate stenosis (<50% & 50-69%) was quite high while prevalence of severe stenosis (>70%) was low. Stenosis was more common in men at all ages than women. Atherosclerotic plaques were mostly found at the site of carotid bifurcation.

With increase in peak systolic velocity of ICA, MRI, DWI, MCA, ASPECT score decreases. Increase in CIMT of carotid artery and grading percentage of stenosis is associated with decrease in MRI, DWI, MCA, ASPECT score.

4. Discussion

The present analysis showed that ischemic stroke is common in both sexes with male predominance. This corresponds to study by Tegos *et al*[18]. Hypertension had shown strongest positive correlation with ischemic stroke in territory of carotid artery which is consistent with study done by Shivani *et al* [19]. In our study we found plaque in 37% cases which was more than detected by study done by Sehrawat *et al*[20], (33.94%). The plaques were classified according to their anatomical location. The right side was affected more than the left side which is consistent with findings detected by Sehrawat *et al*[20]. The plaques formed in the carotid vessels were divided into hypoechoic plaque, echogenic plaque and calcified plaque. In our study we had found that echogenic plaques were more common which was consistent with findings detected by Sehrawat *et al*[20]. In this study, we found plaque in 37% patients out of which 54.1% had right side involvement as compared to 45.9% on left side. This finding is more than as detected by Sehrawat *et al*[20].

In our study we found that the carotid bifurcation was the most common site involved by the atherosclerotic plaque followed by ICA .On right side, 35% plaques were present at bifurcation and on left side 23.5% were present at bifurcation. This findings were similar to study done by Sethi *et al*[21] .

Plaques are more common at bifurcation due to reversal of flow transiently, separation of flow and eddy formation in these areas [22]. In our study we found that the increase in CIMT of carotid artery is associated with increase in plaque formation and ischemic stroke. These findings are consistent with study done by Kazmierski [23] & O'Leary *et al* [24].

In our study there was negative correlation of MRI, DWI, MCA, ASPECT score with CIMT of carotid artery, finding suggesting MRI-DWI, ASPECT score decreases with increase in CIMT of carotid artery.

Our study suggested that PSV is an important flow parameter, more specifically applying to stenosis, and a predictive marker for ischemic cerebral lesions. These findings were consistent with study done by Gunduz *et al* [25].

Out of 37 cases who had stenosis, the prevalence of mild stenosis (<50%) was 59.45% and severe stenosis (>50%) was 40.5%. This correlates with study by O'Leary *et al* [24].

According to the criteria mentioned by Grant *et al*., (PSV >140 cm/sec) was observed in patients with >

70% stenosis of carotid artery. In our study, PSV increased with the increase in stenosis [26]. PSV is considered the best parameter since it is easy to measure. Grant *et al*., also found that mean PSV increases with increase in grade of stenosis [27].

MRI is considered as gold standard for diagnosis of stroke. In conclusion, sensitivity of predicting stroke by carotid Doppler is 56.9%. This study shows that carotid Doppler is an important non invasive diagnostic tool. It can be used for screening in high risk asymptomatic patients and patients with history of cerebral vascular event for guiding treatment. Thus it should be used as first line investigation in these patients and will determine treatment plan for patients in places where NCCT head and MRI brain facility is not available. It will also complement NCCT head negative patients where MRI brain facility is not available. Seventy percent of population lives in villages and cannot have access to big cities where good diagnostic infrastructure like NCCT and MRI is available. In developing countries like India, where facilities to detect acute ischemic stroke is not available in small towns, tehsils and even districts, Carotid Doppler can serve as low cost inexpensive tool for screening of acute ischemic stroke patients and can initially guide physicians to plan treatment.

There were few limitations in our study; on duplex sonography calcified plaque in the carotid artery obscured the area of examination due to its posterior acoustic shadowing. However, the change in position to postero-lateral view was helpful in some cases, especially those involving the smaller segment of vessels. Duplex examination was difficult in uncooperative patients.

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