Original Research Article

Carotid Doppler in Evaluation of a cute Cerebral Stroke and its Correlation with Computed Tomography of Brain

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Abstract

Introduction: Stroke can be defined as an acute central nervous system injury with an abrupt onset. Acute ischemia constitutes approximately 80% of all strokes and is an important cause of morbidity and mortality.Carotid doppler ultrasonography remains the main stay for the evaluation of extracranial carotid vessels. It has well established good accuracy in comparison with angiography studies. Besides estimating the degree of stenosis, the biggest advantage of sonography is its ability to identify and characterize plaque and identify plaques with higher risk of embolization with the use of high resolution ultrasound. **Objective:** To evaluate stroke patients with carotid ultrasound for : The thickness of intima-media Presence of plaque and its characterization Analysis of spectral waveforms in extracranial carotid vessels Estimation of percentage of stenosis To establish a correlation between the percentage of stenosis and type of infarct on CT brain.To establish a correlation between type, site of plaque, and risk of infarction in patients of stroke. **Materials and Methods:** This was a prospective observational study done for a Two year period from November 2017 to October 2019.Present study was undertaken after approval from hospital ethical committee. In this prospective study, 50 patients with symptoms of acute cerebral stroke referred for CT imaging and carotid doppler were included in the study. This study was carried out in patients who had symptoms and signs of acute cerebral stroke at our institute. The patients underwent computed tomography (CT) scan study prior to the color Doppler sonography of carotid arteries and findings were documented. Patients with symptoms of stroke and transient ischemic attack such as sudden loss of consciousness, altered sensorium, aphasia, slurring of speech, diminution or loss of vision. The data gathered from the colour doppler examination consisted of Peak Systolic velocity of common carotid artery Peak systolic velocity of internal carotid artery Velocity ratios between Internal carotid artery and common carotid arteries. Plaque characteristics as seen on the real time image. The presence of Spectral broadening. All the examination was performed with a Doppler angle of 60 degrees Colour Doppler examination of the carotid arteries was done using images from Philips affinity 50G ultrasound machine with probe frequency of 5-12 MHZ in department of Radiodiagnosis from November 2017. CT examination was performed on multidetector 16 Slice CT Siemens Somatom Emotion. **Results:** Fifty patients with symptoms of acute anterior cerebral stroke were included in this study. Patients with symptoms of posterior circulatory stroke were excluded from the study. This study is a prospective cross-sectional study. Males were more commonly affected than females. Most of the patients in this study come under the age group of 60-69 years. Right-sided involvement was noted in 56%, left sided involvement was noted in 38%,and bilateral involvement was noted in 6% of cases.The mean intima-media thickness was 1.246 mm. The thickness of the intima-media was more in higher age groups, indicating the progress of atherosclerosis with age. Majority of the patients had 40-59% of stenosis. The most common type of plaque noted in this study is a completely echogenic plaque, i.e.homogenous plaque.Large-sized cortical infarcts were most common during the study. There was a significant correlation between the type of plaque and the percentage of stenosis. Completely echogenic plaque is associated with a higher percentage of stenosis. There was a significant correlation between the location of the plaque and the risk of infarction.Carotid doppler has an overall sensitivity of 84% in cerebrovascular stroke patients. **Conclusion:** Color Doppler examination is a non invasive, economical, safe, reproducible, and less time-consuming method of demonstrating the cause of cerebrovascular insufficiency in the extracranial carotid arterial system and will guide in instituting the treatment.In this study, there was a significant association between the size of infarct in CT Brain and the amount of stenosis in Internal Carotid Artery on color doppler. There was also a significant association between the size of infarct in CT Brain and the amount of stenosis in ICA on color doppler. There was a high prevalence of carotid artery disease, as evidenced by increased intima-media thickness, plaques, and significant stenosis of internal carotid arteries in patients with stroke in this study. This study highlights the significance of the doppler ultrasonography in this stroke prevention effort through the surveillance of atherosclerosis, which can predispose a person to cerebral ischemia.

Keywords: Carotid Artery, Color Doppler Sonography, Atheroscelerosis, cerebrovascular, CT-Scan

Introduction

Stroke can be defined as an acute central nervous system injury with an abrupt onset. Acute ischemia constitutes approximately 80% of all strokes and is an important cause of morbidity and mortality. Indian surveys show that hemiplegias due to strokes have a prevalence of 200 per 1 lakh persons, constituting nearly 1.5% of all urban hospital admissions, 4.5% of medical and 20% of neurological cases [1]. Carotid artery stenosis (CAS) is a major risk factor for stroke. Approximately 20-30% of all the ischemic strokes are known to be caused by carotid occlusive disease. Carotid doppler ultrasonography remains the main stay for the evaluation of extracranial carotid vessels [2]. It has well established good accuracy in comparison with angiography studies. Duplex sonography combining high-resolution imaging and Doppler spectrum analysis has proved to be a popular, noninvasive, accurate, and cost-effective means of detecting and assessing carotid disease. If timely endarterectomy of the carotid arteries is performed, many stroke cases may be prevented. This necessitates an evaluation of the extracranial carotid artery system. In symptomatic patients like those with hemispheric symptoms or TIA, carotid ultrasound may be the only diagnostic imaging modality performed before carotid Endarterectomy [3]. Besides estimating the degree of stenosis, the biggest advantage of sonography is its ability to identify and characterize plaque and identify plaques with higher risk of embolization with the use of high resolution ultrasound. Plaque can be characterized into relatively high risk groups for containing intra-plaque hemorrhage which is thought by many to be the precursor of plaque ulceration [4].

Purpose of the Study

To evaluate stroke patients with carotid ultrasound for:

- The thickness of intima-media
- Presence of plaque and its characterization
- Analysis of spectral waveforms in extracranial carotid vessels
- Estimation of percentage of stenosis
- To establish a correlation between the percentage of stenosis and type of infarct on CT brain.To establish a correlation between type, site of plaque, and risk of infarction in patients of stroke.

Materials and methods

This was a prospective observational study done for a Two year period from November 2017 to October 2019**.**Present study was undertaken after approval from hospital ethical committee.

In this prospective study, 50 patients with symptoms of acute cerebral stroke referred for CT imaging and carotid doppler were included in the study. This study was carried out in patients who had symptoms and signs of acute cerebral stroke at our institute. The patients underwent computed tomography (CT) scan study prior to the color Doppler sonography of carotid arteries and findings were documented. Patients with symptoms of stroke and transient ischemic attack such as sudden loss of consciousness, altered sensorium, aphasia, slurring of speech, diminution or loss of vision.

The data gathered from the colour doppler examination consisted of

- Peak Systolic velocity of common carotid artery
- Peak systolic velocity of internal carotid artery
- Velocity ratios between Internal carotid artery and common carotid arteries.
- Plaque characteristics as seen on the real time image
- The presence of Spectral broadening.

All the examination was performed with a Doppler angle of 60 degrees Colour Doppler examination of the carotid arteries was done using images from Philips affinity 50G ultrasound machine with probe frequency of 5-12 MHZ in department of Radiodiagnosis from November 2017.

CT examination was performed on multidetector 16 Slice CT Siemens Somatom Emotion.

Data collected from the CT examination consisted of

- Side of infarct : Right , Left
- Vascular territory : Middle Cerebral Artery , Posterior Cerebral Artery, Anterior Cerebral Artery , Posterior Cerebral Artery
- Location: Cortical or subcortical infarct.
- Size of infarct : Small or Large

Results

This study is a prospective observational study conducted in a total of 50 patients included in this study for a period of 2 years. Out of 50 patients, there were 20 females and 30 males. The age of the patients ranged from 32 to 89 years. The mean age of patients was 56.26 ±2.3 SD years. Majority of the patients i.e, 26 % of them were in the age range of 60-69 years. Out of 50 patients, 28 patients had involvement of the disease on left side. 19 patients had disease involvement on right side. 3 patients had bilateral involvement. The intima-media thickness of extracranial carotid arteries is a measurable index of the presence of atherosclerosis [10,11].It is thought to be associated with risk factors for stroke. The intima-media thickness at the bifurcation and the presence of plaque are more directly associated with risk factors for ischemic heart disease [12]. Intima-media thickness measurements must be obtained from a gray-scale image, not from a color Doppler image. Higher-frequency linear transducers (>7 MHz) with compound and harmonic imaging to reduce the near field artifacts are recommended for use [13].

The thickness of intima-media is considered as a surrogate marker for atherosclerotic disease not only in the vascular system of the brain but also in the whole arterial system [17]. The intima-media thickness of extracranial carotid arteries is a measurable index for the presence of atherosclerosis. The thickness of intima media in the Common Carotid Artery is thought to be associated with risk factors for stroke. Out of 50 patients, only 5 i.e 10% patients had intima medial thickening within normal limits i.e less than 0.8mm. While 45(90%) patients had intima medial thickening of more than 0.8mm. In our study of 50 patients, 2 patients (4%) had no stenosis. 2 patients had complete occlusion of ICA with 100% stenosis.4% of patients had 80-89% of stenosis.12% of patients had 60-79% of stenosis.Majority of the patients i.e 21 out of 50 patients had 40-59% of stenosis. 17 patients had 1-39% of stenosis. The principal arterial pathology detected in the carotid artery disease by B mode sonography is atherosclerotic plaque. A plaque is an echogenic material encroaching on the lumen of the artery and produces a signal void. When correlation was calculated for type of plaque and percentage of stenosis, there was a significant correlation between type IV plaque and incidence of stenosis. Pearson correlation coefficient r = 0.8799.

17 patients with type IV plaque i.e, echogenic plaque showed stenosis ranging from complete stenosis to 1-39% stenosis.11 patients with type III plaque i.e., echogenic plaque with small echolucent areas showed stenosis of varying levels.In our study, atherosclerotic changes in the form of atheromatous plaques were found to be the leading cause of obstruction. The type of plaques and location of these plaques have been evaluated. Of the 45 patients having a plaque in the extracranial carotid system, 18(40%) patients had bilateral involvement, 12 (26%) patients had a plaque on the right side, and 20

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(34%) patients had a plaque on the left side. The remaining 5 (10%) patients out of 50 showed no evidence of plaque. Echogenic type of plaque was the most common type of plaque in our study, which includes 18 patients (36%). 12 patients (24%) had an echogenic plaque with small echolucent areas.10 (20%) patients had echolucent plaques. When correlation was calculated for percentage of stenosis and size of infarct on CT, there was a significant correlation between percentage of stenosis and size of infarct. Pearson correlation coefficient r = 0.7685 and p value < 0.01. 2 cases of complete stenosis of ICA had a large sized infarct on CT. Both cases of 80-89% stenosis showed large sized infarct on CT. 6 cases of 60-79% showed large sized infarct. This study included 50 patients diagnosed with stroke on Computed Tomography of brain who underwent carotid doppler retrospectively .Carotid doppler showed 84% sensitivity in the detection of stroke.

Table 1: Side of disease involvement

SIDE INVOLVED	NO OF PATIENTS
RIGHT	22 (44%)
LEFT	28 (56%)
BOTH	3 (6%)

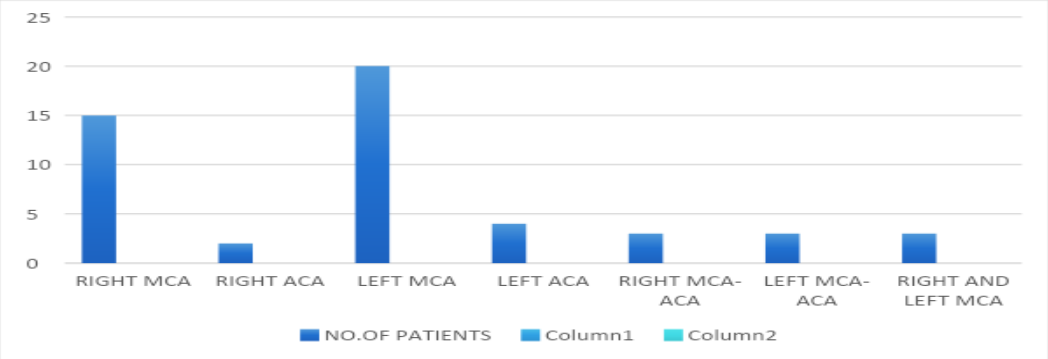

Fig 1: Distribution according to location of infarct on CT

Discussion

The main role of carotid doppler sonography in the detection of occlusive lesions is in the extracranial course of the common carotid and internal carotid arteries. Stroke syndrome consists of the rapid development of a focal neurological deficit that is usually localized to an area of brain supplied by a specific artery. The word stroke indicates brain cell death caused by infarction resulting in deficit enduring for days or longer. Two randomized clinical trials, the North American Symptomatic Carotid Endarterectomy Trial (NASCET) and European Carotid Surgery Trial (ECST), have clearly shown the advantage of Endarterectomy in symptomatic patients with greater than 70 % carotid stenosis (C.RANKE 1999). Ultrasonography is unique among all the vascular imaging procedures, in that it can assess plaque composition. Sonographically detected plaque characteristics can have prognostic value and may be useful for the selection of medical and surgical therapy. Our present study consists of evaluating the extracranial carotid artery system in 50 patients of acute stroke with color doppler and correlation with computed tomography of the brain. The prevalence of atherosclerosis increases with age. In our study, out of 50 patients, there were 20 females and 30 males. The age of patients ranged from 32 to 89 years. The mean age of patients was 56.26 ±2.3 SD. Out of 50 patients in this study, 28 patients had involvement of the disease on left side. 19 patients had disease involvement on right side. 3 patients had bilateral involvement.

Table 2: Criteria for the diagnosis of internal carotid artery stenosis with gray-scale and doppler us.

	PRIMARY PARAMETERS		ADDITIONAL PARAMETERS	
DEGREE OF STENOSIS	ICA PSV (cm/sec)	Degree of plaque(%)	ICA/CCA PSV RATIO	ICA EDV
Normal	<125	None	<2	<40
<50%	<125	<50	<2	<40
50-69	125-230	≥50	2-4	40-100
≥70 but less than near occlusion	>230	≥50	>4	>100
Near occlusion	High,low or undetectable	Visible	Variable	Variable
Total occlusion	Undetectable	Visible,no detectable lumen	NA	NA

Table 3: Correlation between location of plaque and risk of infarction

LOCATION OF PLAQUE	SIZE OF INFARCT	
	SMALL	LARGE
INTERNAL CAROTID ARTERY	1	16
CAROTID BULB	1	5
CCA BIFURCATION	0	2
CCA AND ICA	6	9

Of the 50 patients studied by Merwyn Fernandez [10] et al in 2016, there were 12 patients with significant stenosis and none of the patients showed bilateral involvement. Eight (66.6%) patients had right-sided involvement and 4 (33.3%) patients had left-sided involvement. The thickness of intima-media is considered as a surrogate marker for atherosclerotic disease not only in the vascular system of the brain but also in the whole arterial system [17]. It is believed that thickening of the intima-media thickness of greater than 0.8 mm is considered as abnormal and may represent the earliest changes of atherosclerotic disease [39].

Out of 50 patients, only five i.e., 10% of patients had intima medial thickening within normal limits i.e., less than 0.8mm. While 45 (90%) patients had intima medial thickening of more than 0.8mm.This difference showed statistical significance in our study. Our findings are comparable to the study done by R.Chitrah [12] et al., a total of 82% of vessels in stroke subjects, and 62.5% of vessels in TIA subjects had IMT >0.8 mm. This difference in IMT between Stroke and TIA subjects was statistically significant. In our study of 50 patients, 2 patients (4%) had no stenosis. 2 patients had complete occlusion of ICA with 100% stenosis. 4% of patients had 80-89% of stenosis.12% of patients had 60-79% of stenosis. The majority of the patients i.e., 21 out of 50 patients, had 40-59% of stenosis. 17 patients had 1-39% of stenosis. When correlation was calculated for the percentage of stenosis and size of infarct on CT, there was a significant correlation between the percentage of stenosis and the size of the infarct. Pearson correlation coefficient was r = 0.7685. 2 cases of complete stenosis of ICA had a large-sized infarct on CT. Both cases of 80-89% stenosis showed large-sized infarct on CT. 6 cases of 60-79% showed large-sized infarct. These findings are comparable to the study done by R.Chitrah [12] et al., where p-value was found to be <0.001 for correlation between the percentage of stenosis and size of infarct on CT. In their study, 91.4% had large infarcts in a patient with more than 70% stenosis.

Correlation of colour flow imaging and peak systolic velocities

The percentage of diameter reduction assessed by color flow imaging and peak systolic velocity correlated with each other in 40 patients (80%). Two patients had occlusion of the internal carotid artery in which PSV estimation was not possible. Using ICA/CCA ratio criteria, 10 patients had significant stenosis (ratio >1.8) in which 3 patients had ICA/CCA ratio >3.7. Two patients had complete occlusion on each side, where no flow was detected in the vessel. Hence, the ICA/CCA ratio could not be assessed in them. Bluth.E.I, Kay.D et al. (1986) defined the peak systolic velocity ratio of ICA to CCA greater than 1.8 as an indicator of >80% dimeter stenosis.

We had applied the criteria to our study and found the PSV ratio is less than 1.5 for stenosis <40% in 12 patients,>1.8 for stenosis >60% in 19 patients and > 3 with 70 – 79% stenosis in 9 patients and in 2 patients with complete occlusion of ICA could not be calculated.

End diastolic velocities of ICA

According to w.Zweibel et al., Knighton et al., EDV less than 40cm/sec donot yield any accurate information about the degree of stenosis. If the EDV is more than 40 cm/sec but less than 100cm/sec, we can estimate the stenosis to be ranging from 50-80 %. If the EDV is greater than 100cm/sec, it corroborates to the stenosis greater than 80%. In our study, we found 12 patients with EDV more than 40cm/sec but less than 100cm/sec stratifying them with 50-80% diameter stenosis.

End diastolic velocity ratio

Bluth.E.I, Wetzener et al. found EDV of ICA to ECA ratio greater than 5.5 predicts 80% or more significant stenosis. In our study, we observed <40% stenosis in 12 patients. 19 patients showed EDV of more than 2.6Nine patients showed >70% stenosis with EDV ratio of >3.3 in 9 patients.

Zweibel W.J., Knighton et al. have classified the plaques as follows:

1. Low echogenicity plaques
2. Moderately echogenic plaque
3. Strongly echogenic plaque
4. Calcified plaque with acoustic shadowing

In our study, atherosclerotic changes in the form of atheromatous plaques were found to be the leading cause of obstruction. The type of plaques and location of these plaques have been evaluated. Of the 45 patients having a plaque in the extracranial carotid system, 18(40%) patients had bilateral involvement, 12 (26%) patients had a plaque on the right side, and 20 (34%) patients had a plaque on the left side. The remaining 5 (10%) patients out of 50 showed no evidence of plaque. Echogenic type of plaque was the most common type of plaque in our study, which includes 18 patients (36%). 12 patients (24%) had an echogenic plaque with small echolucent areas.10 (20%) patients had echolucent plaques. In the research done by R.Chitrah [12] et al,36 plaques were echogenic (calcified), and 93 plaques are echolucent (soft) plaques. In both the studies, the most common plaque is echolucent plaque. No ulcerated plaques were found in both these studies. The findings of these studies are in agreement with our study, where echogenic plaques are the commonest type of plaque, and no ulcerated plaques were found in our study. Calcification occurs in plaque in the areas of hemorrhage and necrosis. These calcifications generate strong reflections and distal acoustic shadows. No correlation exists between the presence of calcification and symptomatology. The risk of embolization or rapid progression would depend on plaque composition, especially if it were heterogeneous, diffuse, or focal. In our study, we came across 18 calcified plaques. In a study done by Fernandez [10] et al. they came across 12 calcified plaques out of 50 patients. A study done by R.Chitrah [12] et al. revealed 36 calcified plaques. In our study, the carotid bulb was found to be the most frequent site affected. Plaques in the CCA were seen in 2 (4%) patients. 6 (12%)patients showed plaque in the carotid bulb. 15(30%) patients had plaques in the Common carotid artery extending into the Internal carotid artery. Right-sided plaques were noted in 22 cases, while left-sided plaques were observed in 28 cases. In the study done by R.Chitrah [12] et al., there was a significant association between side and site of plaque with respect to stroke and TIA. The most common site of plaque among stroke was right ICA, and in TIA, patients were left bulb, respectively.

In our study there was significant association between plaque characterization and stroke. In our study there were totally 10 echolucent plaques i.e type I plaques. These type I plaques are considered as dangerous plaques as they have propensity to embolize.

Location and size of infarct on brain

In our study, out of 50 patients, 15 patients had infarct in the right MCA territory, and 20 patients had infarct in the left MCA territory. 3 patients had infarct in both right and left MCA territories. 2 patients had infarct in right ACA territory while 4 patients had infarct in left ACA territory. Three patients had infarct in the right MCA-ACA junctional zone, while three patients had infarct in the left MCA-ACA junctional zone. In a study done by R.Chitrah [12] et al., there was a significant association between the size of infarct and the amount of stenosis in ICA. Subjects with >3mm infarct had >70% stenosis. In our study also there was a significant correlation between the size of infarct and the amount of stenosis. In our study, two patients with complete stenosis or occlusion of ICA had a large cortical infarct on CT. All the 9 patients with more than 60% stenosis, had a large cortical infarct on CT, except for one patient who had a small infarct in the MCA-ACA junctional zone.In the study done by M.Rajesh et al [13].Tthe Middle cerebral artery was the most commonly involved territory of infarction in their research, i.e., (92% of stroke patients). In the study done by Fernandez et al [10]. the middle cerebral artery was most frequently involved. These findings are almost similar to our study. In our study, the middle cerebral artery was the most frequently involved territory in 70% cases. Left MCA was affected in the majority of cases (40%) followed by right MCA in 30% cases

Limitations

Physical challenges such as short muscular neck, a high carotid bifurcation, tortuous vessels, calcified plaques, tracheostomy tubes, surgical sutures, postoperative hematoma or bandages, central lines, inability to lie flat in respiratory or cardiac disease or to rotate the head in patients with arthritis, and uncooperative patients have limited the results of carotid US examination in our study.

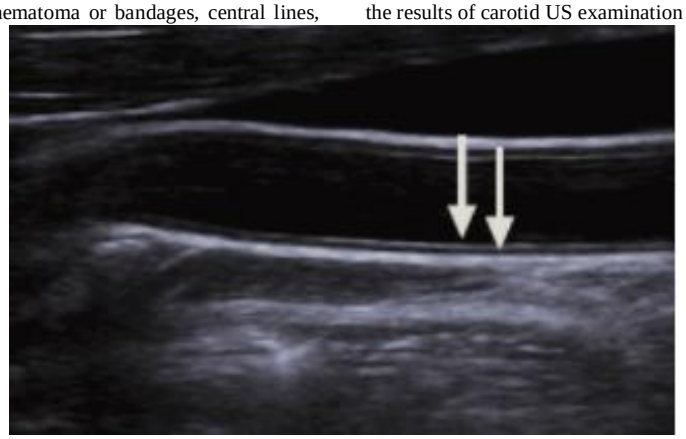

Fig 2: Image showing normal intima media

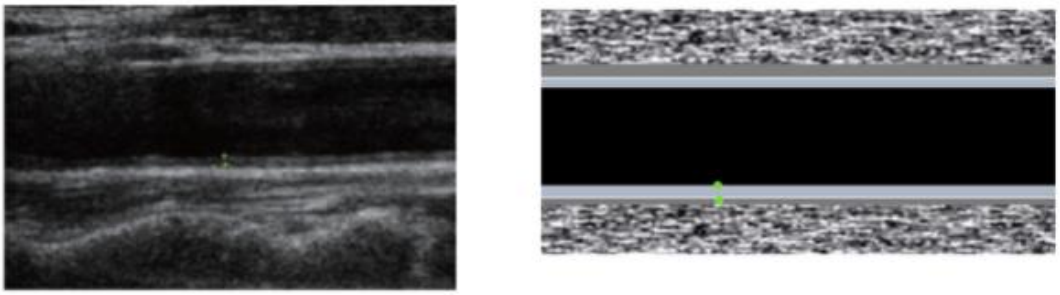

Fig 3: Images showing technique of measurement of intima media thickness.

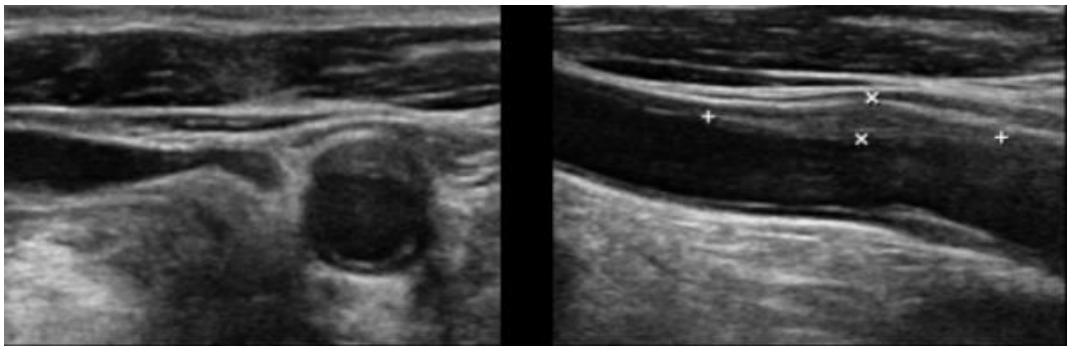

Fig 4: Images showing Evaluation of plaque on short axis and long axis views

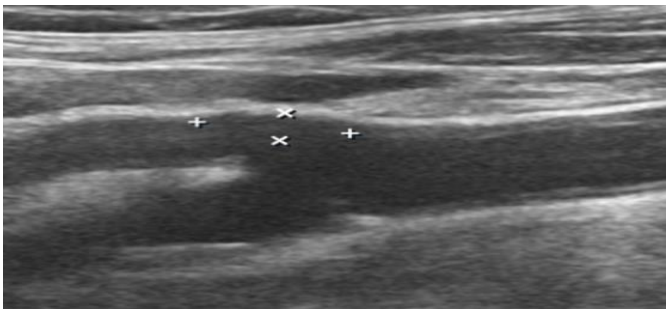

Fig 5: Image showingType I: predominantly hypoechoic plaque with thin echogenic rim

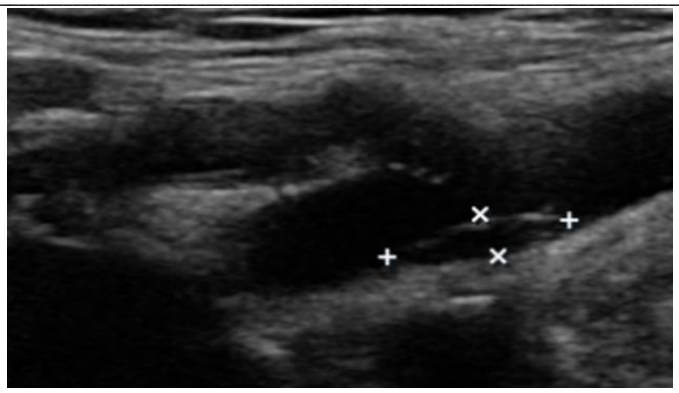

Fig 6: Image showing Type II: echogenic plaque with >50% hypoechoic areas

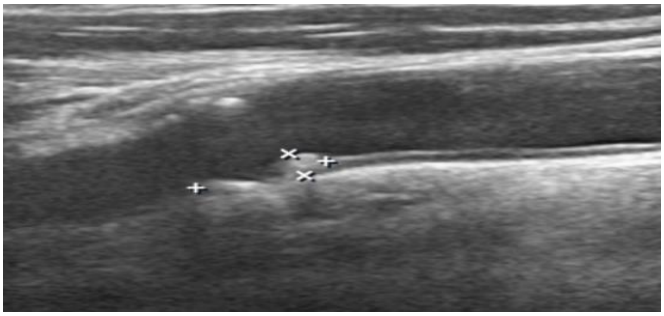

Fig 7: Image showing Type III: echogenic plaque with <50% hypoechoic areas

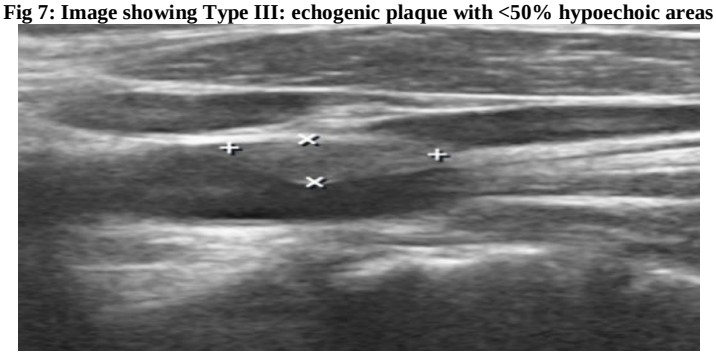

Fig 8: Image showing completely echogenic plaque -Type IV

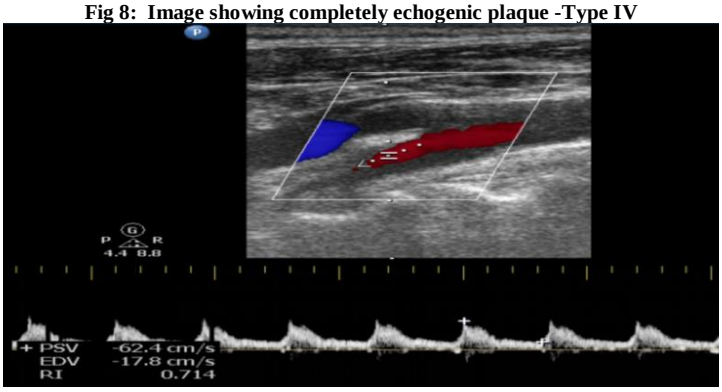

Fig 9: Typical doppler spectrum of common carotid artery

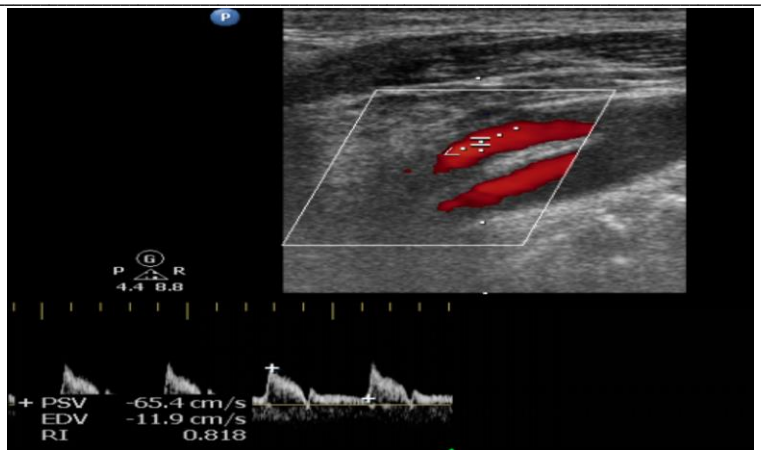

Fig 10: Doppler spectrum of internal carotid artery

Fig 11: Image showing dampened flow in ica corresponding MR Angiography showed stenosis in distal ICA

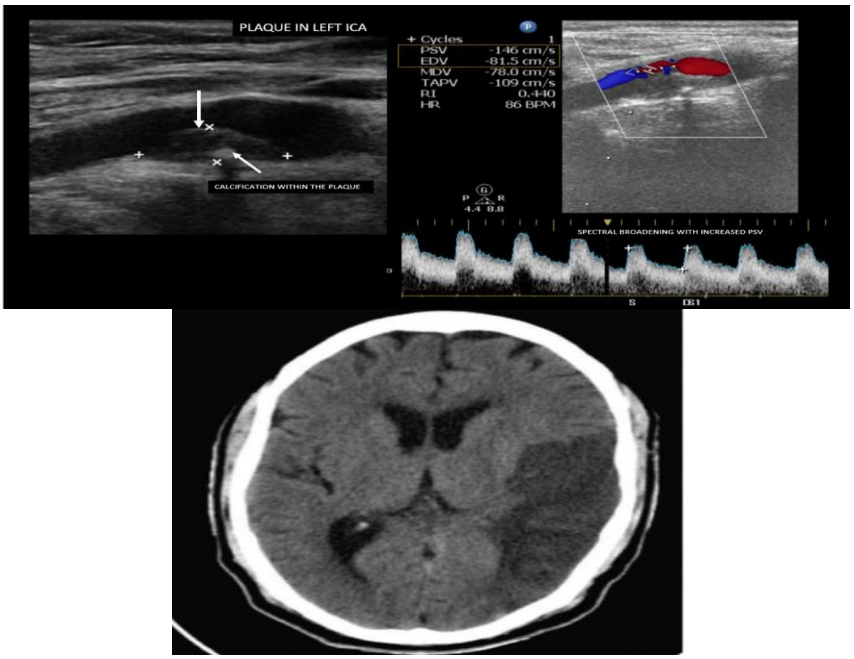

Fig 12: Image showing type II plaque in bulb extending to ICA with increased PSV resulting in 50-69% stenosis, corresponding CT Brain shows large acute infarct in left MCA territory.

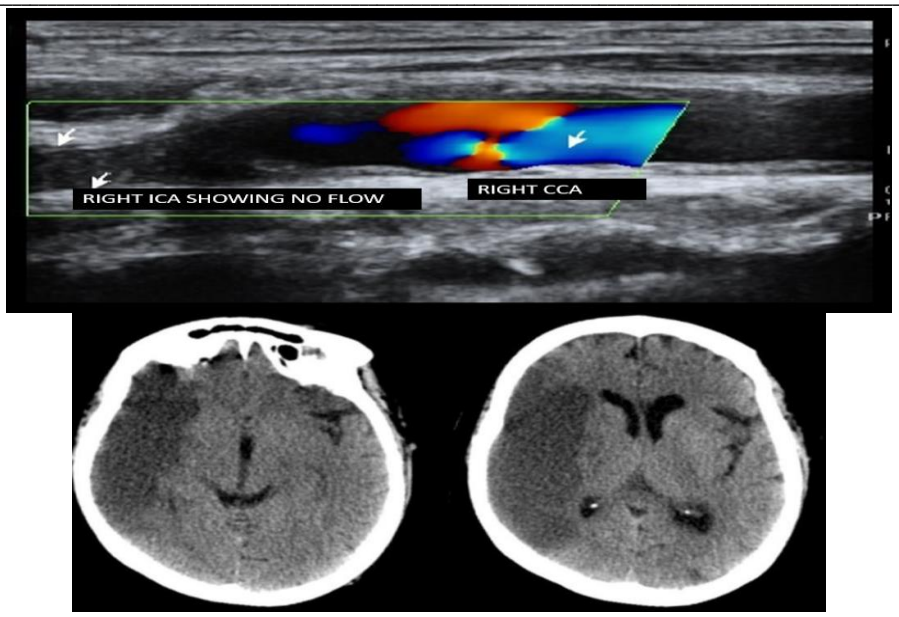

Fig 13: Image showing no flow in right ICA due to thrombus and corresponding CT brain shows malignant right MCA infarct

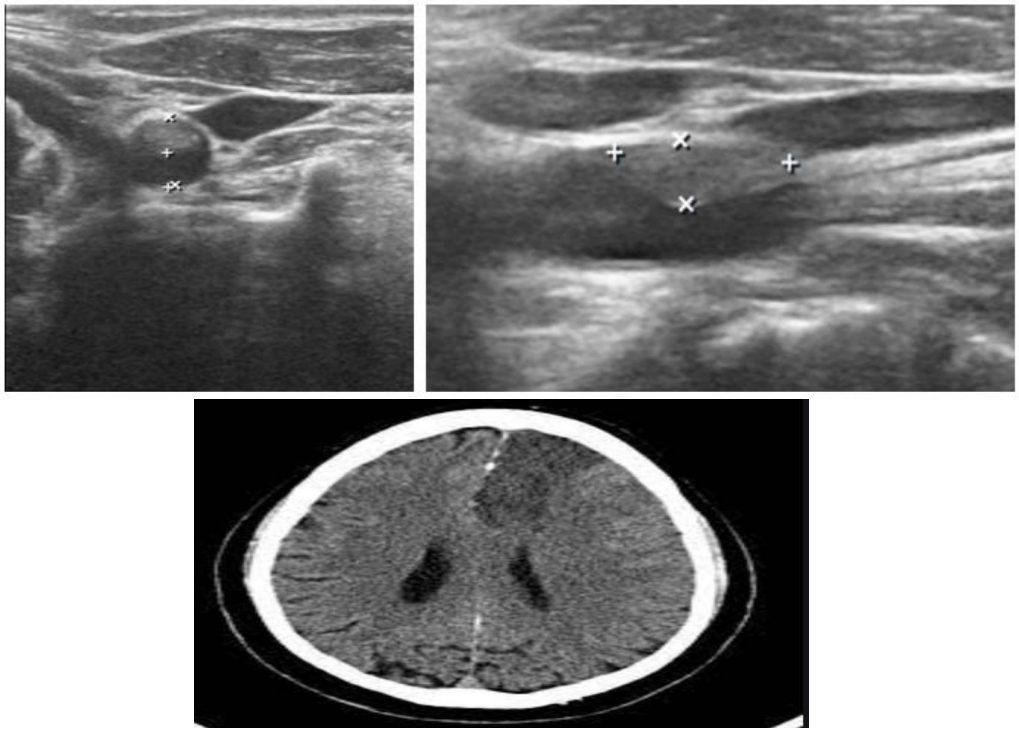

Fig 14: Images showing plaque in left carotid bulb causing 50% stenosis with corresponding CT image showing left ACA infarct

Conclusion

Color Doppler examination is a non invasive, economical, safe, reproducible, and less time-consuming method of demonstrating the cause of cerebrovascular insufficiency in the extracranial carotid arterial system and will guide in instituting the treatment. Doppler sonography has a better role in the evaluation of the morphology of the stenosis, especially plaque morphology, and in estimating the degree of stenosis. In this study, there was a significant association between the size of infarct in CT Brain and the amount of stenosis in Internal Carotid Artery on color doppler. There was also a significant association between the size of infarct in CT Brain and the amount of stenosis in ICA on color doppler. There was a high prevalence of carotid artery disease, as evidenced by increased intima-media thickness, plaques, and significant stenosis of internal carotid arteries in patients with stroke in this study. Hence, carotid Doppler investigation plays an essential role in the prevention of stroke, mainly in patients with risk factors like hypertension, smoking, and hyperlipidemia, although they are asymptomatic. Early detection of plaque helps in treating patients with either medical or surgical management for stroke. This study highlights the significance of the

doppler ultrasonography in this stroke prevention effort through the surveillance of atherosclerosis, which can predispose a person to cerebral ischemia.

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