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Original Research Article

Assessment of carotid arteries in stroke patients by ultrasonography and color Doppler

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ABSTRACT

Background: Prevalence and associated mortality and morbidity rates apprehend stroke as a major health concern worldwide. Atherosclerotic disease of carotid arteries is the most common source of stroke. Quick and effective diagnosis, management and treatment of stroke is essential. Conventional diagnostic imaging techniques lacks the efficacy to rapidly and accurately dragonize stroke. Current investigation is focused towards assessing carotid arteries in stroke patients by ultrasonography and color Doppler to study the locate and study the morphology of lesion in carotid artery and to grade severity and extent of stenosis.
Methods: A prospective observational study was performed on stroke patients of more than 40 years of age. The study was conducted at the department of radio diagnosis in a tertiary care center for a period of 18 months. Varied color Doppler parameters were studied and optimized to assess the morphology and surface of plaques and to determine stenosis
Results: Mean age of the patients with carotid lesion was observed to be 59.7±9.8 years and male patients outnumbered postmenopausal female patients. Hemiparesis was the most common clinical presentation. Majority of patients exhibited raised intimomedial thickness and single or multiple plaques commonly in carotid bulb. Plaques of type II with irregular surface were most commonly observed which exhibited mostly 50-69% stenosis.
Conclusions: The carotid artery embolic occlusion stenosis is the primary cause of stroke. Doppler sonography provides a rapid, noninvasive, relatively inexpensive and accurate means of diagnosing carotid stenosis, to determine the degree of cervical carotid stenosis and plaque morphology.

Keywords: Stroke, Carotid atherosclerosis, Imaging techniques, Ultrasonography, Color Doppler, Plaques

INTRODUCTION

Stroke is clinical manifestation of an abrupt deficit in neurologic activity or cerebral function due to vascular cause.[1,2] Transient ischemic attack (TIA) is the deficit in neurologic activity to a definite area for less than 24 hours and reversible ischemic neurologic deficit (RIND) is abrupt neurological activity for more than 24 hours until one week. Stroke has evidently grown as a major health concern worldwide due to resultant high rate of morbidity and mortality. Atherosclerotic disease of carotid arteries external to cranial cavity is identified as the most common source of emboli leading to stroke.[3] Thus, carotid pathology is significantly associated to stroke and due to the associated high fatality rate, early diagnosis and effective as well as quick management and treatment of stroke is essential.[4] Aging, gender, hypertension, smoking, ischemic heart disease and hyperlipidemia either alone or in combination sever as major causative factors that significantly contributes to carotid atherosclerotic plaque and carotid artery stenosis.[5] Carotid atherosclerotic plaques can be identified by an increase in the combined thickness of the intima and media layers, and subsequently by echogenic material that encroaches on the arterial lumen.[6] Intima media thickness is considered as a surrogate marker for atherosclerotic disease and is

observed that intimomedial thickness greater than 0.8 mm is abnormal and may represent the earliest changes of atherosclerotic disease.[7] Published literature reports that atherosclerosis is a response to injury that is mediated by the endothelial cells that line the arteries.[8,9] Literature additionally reports that denuded or ulcerated carotid plaque surfaces are common sources of cerebral emboli that cause a stroke/ other neurologic events.[8-11] Therefore, ultrasound assessment of plaque surface features is of considerable diagnostic interest. Conventional diagnostic approaches like arteriography, contrasts enhanced dynamic computed tomography and magnetic resonance arteriography lacks the efficacy to accurately and quickly diagnose carotid atherosclerosis as they have the ability only to measure vessel luminal size but cannot characterize vessel wall and associated plaques.[9-12]

Carotid Doppler ultrasonography (CDU) is considered to be an effective and powerful tool for assessing atherosclerosis of the carotid artery.[13] Color Doppler ultrasonography with minor modifications is an economical, non-invasive, readily available and reliable tool with relatively better sensitivity and specificity for assessing carotid atherosclerosis with smallest plaque size.[13] Color Doppler imaging is mainly based on quantifying the degree of stenosis caused by atherosclerosis in a patient with stroke, additionally, intima-media thickness (IMT) of the common carotid artery (CCA) and plaque morphology may also help in assessing the carotid artery atherosclerosis. The distinction between a total vessel occlusion and 99% diameter reduction is crucial since the former is a contra-indication to surgery.[14] Internal carotid artery occlusion on the ultrasonography can be inferred on the basis of the lack of pulsation or expansion of vessel walls but this is unreliable.[15] The diagnosis of occlusion based on the detection of a thrombus-filled lumen, the absence of wall motion characteristics and the lack of Doppler flow signal has a high reported accuracy.[16] Color Doppler improves the ability of ultrasonography to distinguish between occlusion and severe stenosis by allowing a narrow channel to be identified. The ICA PSV and the presence of plaque at grey-scale or color Doppler imaging are primary parameters for the grading of ICA stenosis. If the degree of stenosis is indeterminate according to the primary parameters, then additional parameters including the ICA/CCA PSV ratio and the ICA end-diastolic velocity will be taken into consideration. If the CCA is stenotic, the PSV of the non-stenotic segment of the CCA (point A) proximal to the stenotic segment (point B) may also be measured to calculate the ICA/CCA point A PSV ratio and the CCA point B/CCA point A PSV ratio. Sonographic features of a severe ICA or CCA stenosis may include the following: PSV greater than 230 cm/sec, a significant amount of visible plaque (≥50% lumen diameter reduction on a gray-scale image), color aliasing despite a high color velocity scale setting (≥100 cm/sec), spectral broadening, post-stenotic turbulence at color Doppler and PW Doppler imaging, color bruit artifact in the surrounding tissue of the stenotic artery, end-diastolic velocity of greater than 100 cm/sec, ICA/CCA PSV ratio of 4.0 or greater, and finally a high-pitched sound at PW Doppler imaging.[17] The higher the degree of stenosis, the more likely it was associated with heterogeneous plaques. Heterogeneous plaques were also associated with an incidence of cerebrovascular symptoms (TIA/stroke) that was higher than that inhomogeneous plaque for all grades of stenosis. Heterogeneity of the plaques was reported to be more positively correlated with symptoms than with any degree of stenosis, regardless of the plaque structure.[18]

Thus, Duplex color Doppler ultrasound imaging study of carotid arteries in stroke patients can aid in planning management strategies and deciding whether medical or surgical treatment is required for stroke patients.

Aim and objectives

Aim of current study was to study carotid arteries in patients of stroke by ultrasonography and color Doppler. Objectives of current study were to look for an atheromatous lesion in the carotid artery in patients of stroke, to grade the severity of stenosis of carotid arteries and to study the morphology of plaque in carotid arteries.

METHODS

Study design, population, location and duration

Current investigation was a prospective observational study performed on stroke patients of more than 40 years of age who were referred for ultrasonography and color Doppler evaluation of carotid artery by the department of medicine. The study was conducted at the department of radio diagnosis in a tertiary care center for a period of 18 months from April 2018 to October 2019.

Sample size

In current investigation prevalence of stroke (80%) was taken as the basis for sample size calculation.[19] Sample size calculated using Open Epi software at 95% confidence interval, 80% power and 10% absolute precision was 62; thereby total 70 cases were studied and evaluated in current investigation.

Inclusion and exclusion criteria

Patients of both sexes with age more than 40 years with clinical and radiological diagnosis (on basis of computed tomography of the brain) of acute stroke were included in the study. Patients with a history of head injury, evidence of space-occupying lesion, venous infarct on computed tomography of brain, patients having signs and symptoms of posterior circulation infarct and patients having signs of meningeal irritation were excluded from the study.

Scanning technique[20-22]

Detailed examination procedure was explained to the

patients and examination was initiated after receiving the written informed consent from the participating patients. The examination was done in supine position of patients by taking a transverse scan of the carotid artery from the lowest to highest position of neck behind the angle of mandible. The Doppler was then activated and blood vessels were examined in the longitudinal plane from lower neck towards upward position. Several transducers at different positions were used to examine the carotid arteries in long-axis (longitudinal) planes. Short-axis (transverse) views of the carotid arteries were either obtained from an anterior, lateral, or posterolateral approach, depending on the best visibility of vessels. After delineation of common carotid, internal carotid, bulb and external carotid arteries, vessel wall was assessed and intimomedial thickness of common carotid artery was measured. All focal plaques were considered as abnormal. Once plaques were seen morphology was evaluated by ultrasonography in the form of extent of plaque, location of plaque, texture (echogenic, anechoic) and surface (smooth, irregular) of plaque. Using longitudinal plane with color and spectral Doppler (angle of 40-60°), the extracranial carotid arteries were assessed for velocity from the common carotid artery (CCA) to distal internal carotid artery (ICA) and the vertebral artery. Peak systolic velocities (PSV) and end-diastolic velocities (EDV) were also measured. Observations like: presence or absence of disease; PSV and EDV in the CCA 1-2 cm below the bifurcation and in ICA at the point of highest velocity; nature of the plaque observed e.g. calcified, echo lucent, irregular, smooth etc.; the length and anatomical position of plaque; percentage degree of stenosis and calculation method used i.e. ECST/ NASCET and appropriate number of annotated images that represent entire ultrasound examination in accordance with local protocols and SVT image storage guidelines recorded and documented.

Scanning equipment and parameters

Samsung RS80A machine with linear array transducer L3-12 (frequency range 3-12Hz) were used in current investigation. The optimal color Doppler parameters used in current study were color Doppler sampling window: the color Doppler sampling window (color box) was positioned over the artery to be interrogated. The size of the color Doppler sampling window was adjusted to include all regions of interest. Adjustment of the angle of incidence was achieved by changing pre-set color box angles from left to centre or right, as well as angling the transducer to ensure that the Doppler angle of incidence was less than 60° to the direction of blood flow. Color velocity scale control: for a normal carotid ultrasonography examination, the color velocity scale was set between 30 and 40 cm/sec (mean velocity), however in case of diseased artery the color velocity scale was shifted up or down according to the mean velocity of blood flow to demonstrate aliasing only in systole. Color gain control: the color gain was beset so that color just reached the intimal surface of the vessel. Doppler angle: angle was aligned parallel to the vector of blood flow by applying the angle correction or by angling the transducer. Sample volume box and angle correction: the ultrasonography machine calculates the velocity from the Doppler shift frequency reflected from red blood cells within the sample volume box. The position of the sample volume box in a normal artery was in the mid lumen parallel to the vessel wall, whereas in the diseased vessel it was aligned parallel to the direction of blood flow. Color Doppler image shows a tortuous left (LT) ICA. The change in the color depiction of the ICA was not due to change in blood flow velocity but instead reflected changing direction of blood flow relative to Doppler angle of incidence. To sample the velocities at required points, the color box and angle of incidence were corrected by steering the color box or angling the transducer. Spectral broadening: Spectral broadening results from turbulence in the blood flow. Spurious spectral broadening can result from a large Doppler angle, a large sample volume box (>3.5 mm), a sample volume box located close to the vessel wall, or a high PW Doppler gain setting. The size of the sample volume box (also known as the gate) was kept between 2 and 3 mm to avoid sample broadening.

Statistical analysis

Observations of the current investigation were reported in the form of values and their frequencies. Statistical tools like proportion, frequency, mean and standard deviation were used in current investigation. Frequency values were reported in the form of bar graph, pie chart or in clustered column chart form

RESULTS

Age wise distribution of patients participating in current study depicted that maximum number of patients (37%) were in the age group of 51-60 years, followed by 61-70 years (31%). Mean age of the participating patients with carotid lesion was observed to be 59.7±9.8 years (Table 1). Gender based distribution of participating patients revealed that male patients outnumbered female patients, out of total 70 Patients 47 patients were observed to be male whereas 23 were females (Table 1).

Table 1: Distribution of patients based on demographic details.

Parameters	N	Percentage (%)
Age (years)		
41-50	14	20
51-60	26	37
61-70	22	31
71-80	6	8.5
>80	2	2.8
Total	70	100
Gender		
Males	47	67.14
Females	23	32.85
Total	70	100

It was observed through current study findings that none of premenopausal females exhibited carotid lesion, while approximately 56% of postmenopausal females had lesion and it was also observed that in postmenopausal females, incidence of lesion increased with age. Results of current study revealed that majority of patients (65.7%) exhibited hemiparesis as the most common clinical presentation. Symptoms like cranial nerve palsies, aphasia, monoparesis and quadriparesis were also observed in participating patients (Table 2).

Table 2: Distribution of patients based on clinical presentations and raised intimomedial thickness.

Parameters	N	Percentage (%)
Clinical presentation		
Hemiparesis	46	65.7
Cranial nerve palsy	9	12.8
Aphasia	5	7.1
Monoparesis	5	7.1
Quadriparesis	5	7.1
Total	70	100
Intimomedial thickness		
Increased	50	71.4
Normal	20	28.5
Total	70	100

Majority of patients (71.4%) also exhibited raised intimomedial thickness which was calculated in common carotid artery 1-2 cm below the carotid bifurcation, thickness of <1 mm was considered to be normal (Table 2 and Figure 1). Among the participants plaques were seen in 56 patients out of total 70 patients (80.0%), 37 patients exhibited multiple plaques and multiplicity of plaques may be a consequence of more advanced stage of the disease in stroke patients. Total 27.1% of total patients had single plaque in carotid arteries and around 80% of total patients showed carotid lesion (Table 3). It was revealed through current study findings that most common site for plaque was found to be carotid bulb; as out of total plaques, 72 (52.5%) were observed to be located in bulb followed by 32.1% of plaques in carotid artery and 15.3% of plaques located in internal carotid artery (Table 3).

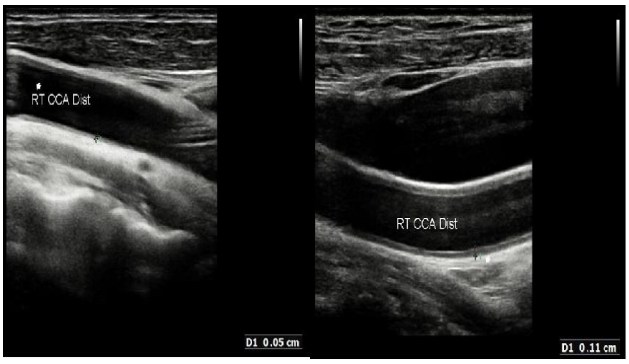

Figure 1 (A and B): Normal intimo-medial thickness and increased intimo-medial thickness in common carotid artery.

Results of current study depicted that type II plaque (echo lucent with small echogenic) was observed as the most common (33%) type of plaque in stroke patients, followed by type III (echogenic with small echo lucent areas) (26.4%) and type 1 (echo lucent) (25.7%), only 11% and 3.6% of plaques were of type IV (echogenic) and type V (echogenic with posterior acoustic enhancement) resp. (Table 3). Overall, it observed that echogenicity of plaques corresponds to stroke. Out of total 136 plaques, 2 showed total occlusion and so their morphology could not be evaluated accurately, of remaining 134 plaques, 85 showed irregular surface (63.4%), 34 showed smooth surface (25.3%) and remaining 15 having ulceration (11.1%). It was observed that irregular surface was most common with plaques in stroke patients (Table 3). Results of gray scale B mode imaging revealed that out of 136 plaques, most plaques (44.1%) showed 50-69% of stenosis and 22.7% of plaques showed less than 50% stenosis and 27.2% plaques showed equal to/ more than 70% stenosis (Figure 2-5). It observed that similar results with no differences in calculated percentage of stenosis was observed through color Doppler studies (Table 4).

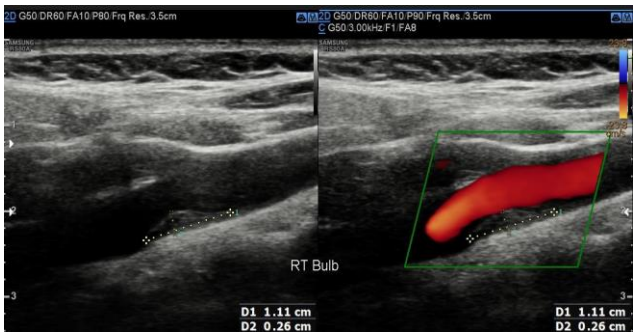

Figure 2: Type II plaque in right carotid bulb.

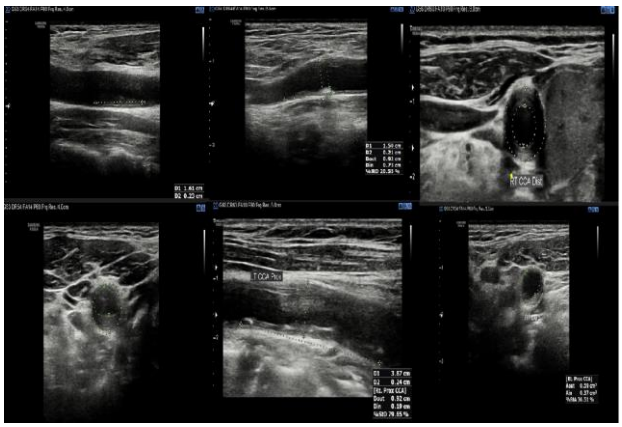

Figure 3: Type I smooth plaque, type II plaque in left CCA with a smooth surface causing less than 50% luminal stenosis, circumferential type II smooth plaque in right distal CCA, eccentric type II smooth plaque in right mid CCA causing less than 50% stenosis, type IV irregular and type II smooth plaque in left proximal CCA causing nearly 80% luminal stenosis and type III smooth plaque causing less than 50% stenosis.

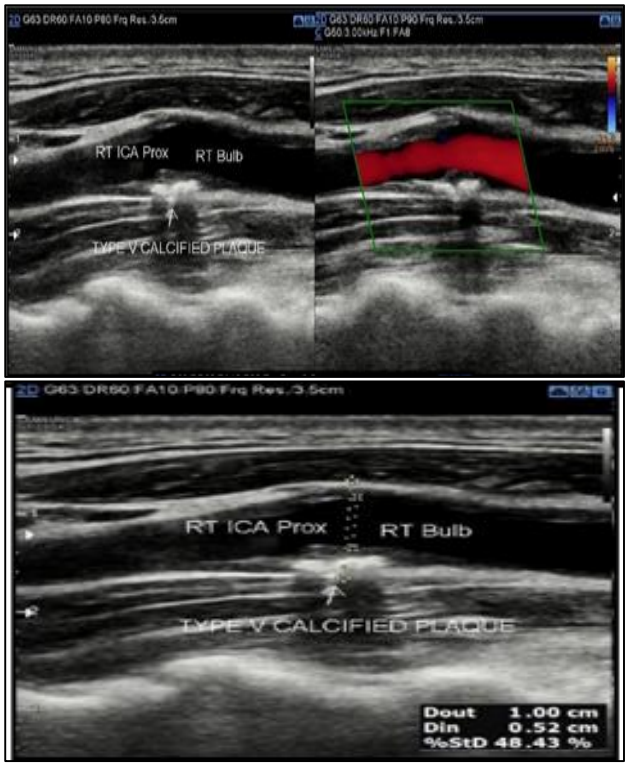

Figure 4: Type V plaque causing acoustic shadowing and nearly 48% luminal stenosis in right bulb extending in right ICA.

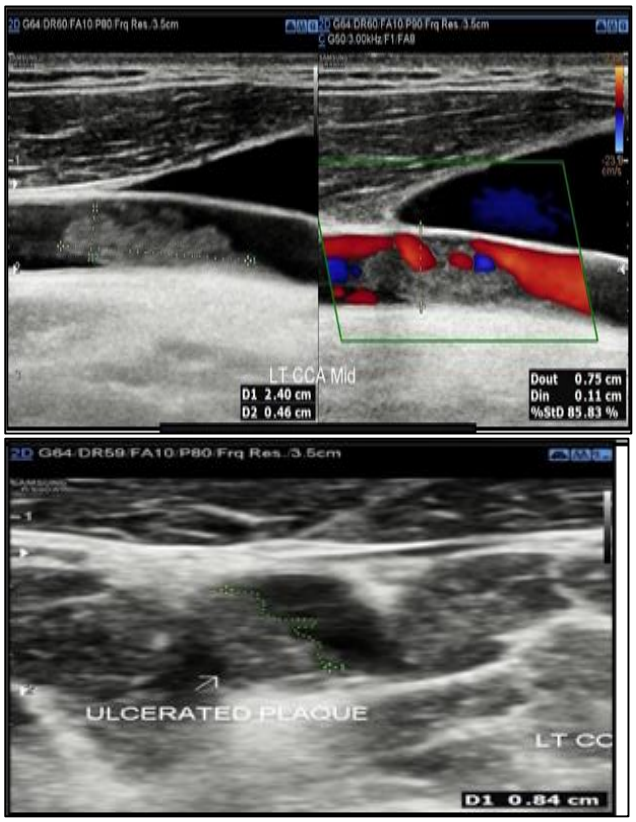

Figure 5: Ulcerated plaque in left mid-CCA causing 55% of luminal stenosis in a patient presented with hemiplegia.

Table 3: Distribution based on number, location, grade and surface of plaques.

Parameters	N	Percentage (%)
Number of plaques		
None	14	20
01	19	27.1
≥2	37	52.8
Total	70	100
Location of plaques		
Carotid bulb	71	52.5
Common carotid artery	44	32.1
Internal carotid artery	21	15.3
Total	136	100
Morphological grade of plaques		
I	35	25.7
II	45	33
III	36	26.4
IV	15	11
V	5	3.6
Total	136	100
Surface of plaque		
Irregular	85	63.4
Smooth	34	25.3
Ulcerated	15	11.1
Total	134	100

Table 4: Distribution of plaques based on incidence of carotid artery stenosis identified through gray scale B and color Doppler imaging techniques.

Gray scale B	N	Percentage (%)
% Stenosis		
<50	31	22.7
50-69	60	44.1
≥70	37	27.2
Near total occlusion	06	4.4
Total occlusion	02	1.4
Total	136	100
Color Doppler		
<50	31	22.7
50-69	60	44.1
≥70	37	27.2
Near total occlusion	06	4.4
Total occlusion	02	1.4
Total	136	100

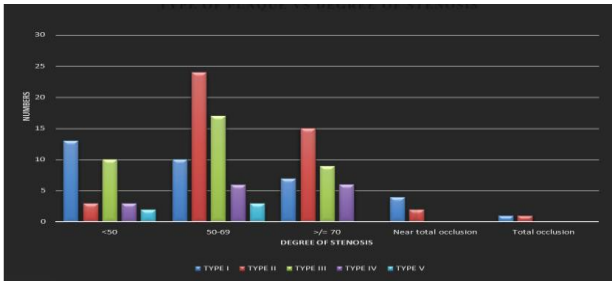

Figure 6: Distribution based on type of plaque vs. degree of stenosis.

Power Doppler used in plaques to demonstrate complete occlusion. Results of type of plaque vs. degree of stenosis study revealed that most common type II plaques caused 50-69% of stenosis, whereas type I plaque found to be the most common plaque to cause <50% stenosis (Figure 6).

DISCUSSION

Published prevalence reports claims that incidence of carotid artery atherosclerosis increases with age.[23] Literature reports also reveals that overall incidence carotid artery atherosclerosis in males is greater than that in females due to the protective role of female hormones however after menopause, when this protective effect wanes, the rates of diseases become similar in both the genders.[24] Current study findings reveal that 51 to 60 years was the most common age group, accounting for 37% carotid artery atherosclerosis patients the mean age of stroke was observed to be 59.7 years. Number of male patients with carotid artery atherosclerosis (67%) outnumbered female patients (38%), also none of the premenopausal females exhibited carotid lesions. while approximately 56% of postmenopausal females had carotid lesion, however it was observed that in postmenopausal females, the incidence increased with age. Similar to current study findings report published by Nasreen et al and Sethi et al revealed majority of patients with carotid artery atherosclerosis (56%) of more than 60 years of age with mean age of 60.03 years.[25,26] Gender based distribution of carotid artery atherosclerosis patients reported by Malik et al stated 64% males and 36% females, also the authors reported none of the premenopausal females had lesion and approximately 40% of postmenopausal females had abnormal carotid Doppler which was in close accordance to current study observations.[27]

Hemiparesis was observed as the most common clinical presentation in the present study followed by cranial nerve palsies, aphasia and monoparesis, the findings were similar to reports published by Malik et al who reported hemiparesis in majority (76%) of patients. Atherosclerotic plaque is initially revealed sonographically by an increase in the combined thickness of the intima and media layers, and subsequently by echogenic material that encroaches on the arterial lumen.[6] Present study findings reveal that 50 out of 70 patients had increased intimomedial thickness (IMT) accounting for 71.4% of cases, similar findings were published in Laith et al report.[28] Published literature reveals that embolic occlusion of intracranial arteries is the primary cause of stroke, rather than an immediate hemodynamic effects of carotid stenosis or occlusion.[29,30] Observations made and reported in published literature also reveals that denuded or ulcerated carotid plaque surfaces are common sources of emboli that causes stroke; thus, ultrasound assessment of plaque surface is of considerable importance diagnostically.

In current study, around 80% of total patients exhibited carotid lesion out of which single plaque was observed in 27.2% while multiple plaques were observed in 52.8% of patients. Results of current study were in close resemblance to a report published by Malik et al which stated 44% of stroke patients with multiple plaques.[27] Current study revealed that carotid bulb was the most common site for plaque, followed by common carotid artery. Sethi et al observed similar findings, with 50% plaques located in carotid bulb, 30.6% in common carotid artery and lowest number of plaques in the internal carotid artery.[26] Current study findings reveal that out of total 136 observed plaques; majority (33%) of plaques were of type II, followed by type III plaques (26.4%) it was also observed that type II plaque was the most common plaque type to cause 50-69% stenosis, whereas type I plaques commonly resulted in <50% stenosis. Current study observations revealed that plaques with irregular surfaces were most frequently seen followed by smooth surface plaques and ulceration was demonstrated only in 11.1% of total plaques. Findings and observations similar to current study were reported by Malik et al and Sethi et al.[26,27]

The distinction between a total occlusion and a 99% diameter reduction is crucial since the former is a contra-indication to surgery.[31] In the present study, out of 136 plaques, 60 plaques showed 50-69% stenosis on B mode and color Doppler both. Differentiation of near-total from total occlusion was precisely done by color and power Doppler assessment. However, there were minor differences in percentages between detection of stenosis by color and greyscale. Malik et al reported majority of the plaques in transient ischemic attack patients (72.7%) caused <50% stenosis, while just 28% plaques in stroke patients caused so and majority of plaques in stroke patients (43.7%) caused 50-69% stenosis.[27] Sultana et al reported distribution of degree of stenosis was mild (50%) in 12% of patients, moderate (51-69%) in 50% of patients and severe (>70%) in 20% of patients and near-total occlusion were seen in three (5%) patients also they reported that the presence of stenosis was significantly correlated with older age and the presence of multiple risk factors.[25] Sultana et al reported distribution of degree of stenosis was mild (50%) in 12% of patients, moderate (51-69%) in 50% of patients and severe (>70%) in 20% of patients and near-total occlusion were seen in three (5%) patients also they reported that the presence of stenosis was significantly correlated with older age and the presence of multiple risk factors.[25] These reported findings were in close accordance to current study observations.

Limitations

Limitations of current study were; a number of technical factors may limit the value of ultrasound examination like; high carotid bifurcation, severe arterial tortuosity and obesity. A tortuous vessel may result in a spurious increase in velocity and may also reduce the accuracy of Doppler ultrasound (DUS) imaging. Extensive plaque disease, particularly if calcified, acoustic shadowing may hamper insonation of the area distal to the calcification and affect the imaging accuracy. DUS imaging may also fail to

differentiate between subtotal and total carotid occlusion. Intravenous administration of contrast agents may improve diagnostic accuracy. Large ulceration of plaque can be diagnosed easily, however, the problem is with small ulcerations. Development of 3D ultrasound, which allows a more comprehensive evaluation of the carotid plaque may increase chances of small ulcer detection.

CONCLUSION

The carotid artery stenosis is considered as a well-known risk factor for the development of ischemic stroke. Carotid ultrasonography offers a noninvasive assessment of the extracranial neck portions of the carotid and vertebral arteries for diagnosis of atherosclerotic disease. Doppler sonography provides a rapid, noninvasive, relatively inexpensive and accurate means of diagnosing carotid stenosis, to determine the degree of cervical carotid stenosis and plaque morphology in most patients initially. Embolic occlusion of intracranial arteries is the primary cause of stroke, as opposed to the immediate hemodynamic effects of carotid stenosis or occlusion, so detection of ulcerated, denuded plaques becomes crucial. Sonography can successfully identify large ulcers. Standardized technical parameters, scanning methods, Doppler analysis, and interpretation enhance the accuracy and reproducibility of the results.

Recommendations

Ultrasonography and color Doppler evaluation of carotid arteries is recommended in stroke patients as it is rapid, non-invasive and relatively inexpensive tool which aid in planning the treatment strategy in patients. Unequivocal identification of stenosis of 50% to 99% in neurologically symptomatic patients or 70% to 99% in asymptomatic patients is sufficient to make a decision regarding intervention. Morphology of plaque can provide information regarding present status and future risk of embolization by differentiating and identifying stable and unstable plaques. For evaluating the vessels proximal or distal to the cervical carotid arteries for diagnosis or to plan a therapy, imaging with CTA, MRA, or catheter angiography in addition to CDUS would be recommended.

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