Original article

Extracranial carotid doppler correlation to multidetector CT angiography in ischemic stroke patients

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Abstract
The purpose of this study was to compare the diagnostic value of Color Doppler Ultrasound (CDUS), Computed Tomographic Angiography (CTA), and advantage of their combined use in defining the degree of stenosis and morphological character of atheromatous plaque in ischemic stroke patients. This study was a cross-sectional study with a total of 60 patients having 120 carotid arteries were observed. The percentage of stenosis was measured at the narrowest point by modified NASCET criteria for both CDUS and CTA. Incidence of stroke was highest in the age group 50-70 years with male population commonly affected. Frequency of carotid stenosis was more in male patients aged above 60 years. Hemiparesis was most common symptoms in stroke patients. The various risk factors of carotid atherosclerosis and stenosis included hypertension, diabetes mellitus, hyperlipidemia and cardiovascular disease. Atheromatous plaques with stenosis were most commonly found on right side. Carotid bifurcation was the common site for atheromatous plaque. There was significant correlation between Color Doppler Ultrasound and Computed Tomographic Angiography for detecting 70-100% stenosis. However CTA is more accurate in comparison to duplex ultrasonography in detecting 70-99% stenosis and total occlusion. There was no significant correlation between CDUS and CTA in detecting 20-49% stenosis. Duplex ultrasonography is more sensitive in detecting these lesions. Out of 49 plaques, in this study 11 were soft plaques, 26 were non-homogenous and 13 were ulcerative plaques. Color doppler has better role in plaque characterization. Besides degree of extracranial stenosis, length of the stenosis, site of intracranial stenosis and total number of stenotic sites are better assessed by CTA. Area of effected brain parenchyma and extent of collateral circulation are better assessed by CTA which aids in prognostic value. In conclusion, the advantage of the combined use of CDUS and the CTA in the identification and quantification of ICA stenosis is higher. However ultrasound had a better role in plaque characterization.

Key words: Color doppler, CT angiography, Stenosis, Stroke

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Stroke is one of the leading causes of death more often disabling than fatal. Common causes of ischemic stroke are atherosclerosis with superimposed thrombosis, hypertensive arteriolar sclerosis, embolus from heart, dissection of carotid and vertebral artery, vasospasm due to subarachnoid hemorrhage. Major risk factors associated with stroke are hypertension, cardiac disease, diabetes mellitus, hyperlipidemia, cigarette smoking, alcohol abuse, physical inactivity, carotid stenosis and transient ischemic attack. High degree internal carotid stenosis is responsible for 20-30% of all ischemic strokes.

Treatment of stroke depends on the most accurate and earliest diagnosis, as time is a crucial factor for appropriate therapy to reduce the risk of stroke and long term sequelae. Several modalities like Color Doppler Ultrasound (CDUS), Digital Subtraction Angiography (DSA), Computed Tomography Angiography (CTA) and Magnetic Resonance Angiography (MRA) are available for the assessment of carotid artery disease.

Ultrasonography remains the most accurate non-invasive modality for evaluation of carotid artery disease. It provides information about the degree of carotid stenosis, the velocity and character of blood flow and plaque morphology. However there are several pitfalls that may mislead the operator to falsely interpret the color and spectral doppler findings.

The purpose of this study was to estimate the diagnostic value of extra cranial carotid and vertebral artery doppler and Computed Tomography Angiography, to delineate the pitfalls during imaging, interpretations and limitations of Color Doppler Ultrasound, their combined use (CDUS+CTA) in the detection and quantification of severe ICA stenosis and to detect an established and preventable cause of stroke, which may subsequently help to plan future treatment modality (medical /surgical) for prevention of further cerebrovascular events.

Material and methods

This was a cross sectional study on a consecutive series of patients. A total of 60 patients (120 carotid arteries) having transient ischemic attack (TIA), reversible ischemic neurologic deficit (RIND), prolonged ischemic neurological deficit (PIND), or cerebrovascular insults (CVI) admitted to S. C. B. Medical college & Hospital, Cuttack were included in this study. The patients included were of both sexes and age above 18 years.

Patients previously operated on for carotid disease, those with already verified thrombosis in the left ventricle and/or in auricle, patients with verified brain tumors, patients with intracerebral hemorrhage, patients allergic to contrast agents, patients with abnormal renal function were excluded from this study.

The risk factors were evaluated by history, physical examination, echocardiogram and laboratory investigations during hospitalization. These included age, sex, hypertension, diabetes mellitus, hyperlipidemia, smoking and ischemic heart disease.

Ultrasoundographic examination was performed with a GE pro-6 machine. Arteries were studied under grey scale, color and spectral waveform using high frequency (3-12MHz) linear probe. The percentage of stenosis was evaluated by the use of the modified NASCET (North American Symptomatic Carotid Endarterectomy Trial Collaborators, 1991) criteria (formula 100 x (A-B)/A). CTA examination was performed with GE 128 MDCTA. 70-100 ml of contrast material was injected intravenously at a flow rate of 4ml/sec with a power injector in right subclavian vein using 18 gauge needle. For optimal timing of the bolus, the bolus tracking method was used. MDCT angiography was performed using following parameters: 100kVp, 180-300mAs, 10mm collimation, 17.5mm/rotation table feed and 0.8sec rotation time. The images were reformatted with a section thickness of 0.625 mm and 3D MIP and VR images were obtained. The percentage of stenosis was evaluated by the use of both axial and coronary maximum intensity projection (MIP) and shaded-surface display (SSD) imaging.

Degree of stenosis were classified into four groups namely 20-40%, 50-69%, 70-99% and stenosis of 100% (total occlusion). Plaque morphology (homogenous / heterogenous, regular/irregular margin, ulcerative /non ulcerative surface, calcified /non calcified plaque) were correlated in both the modalities.

Results

Majority of the patients in this study belonged to the age group of 50-70 years constituting about 70% of the total study population. Median age of presentation is 61 years. The highest numbers of carotid artery stenosis in our study were found in the age group of 61-70 years which was followed by 51-60 years of age group. Thus incidence of extracranial stenosis was more in age above 60 years.
In this study 70% (42 of 60) patients were males and 30% (18 of 60) patients were females. Out of 42 male patients 29 patients (70%) showed carotid stenosis and out of 18 females 8 patients (44%) showed stenosis. So extracranial carotid stenosis was more common in males. The commonest presenting symptom was hemiparesis seen in 42 patients (70%). Monoparesis was seen in 12 (20%) patients, paraparesis in 1 (1.6%) patients, cerebellar symptoms in 1 (1.6%) patients, sudden vision loss in 3 (5%) patients and syncope with dizziness are noted in 1 (1.6%) patients.

In our study 41 patients (69% of total patients) having hypertension. Out of them stenosis was present in 28 cases. So 68% of hypertensive patients showed carotid stenosis. Out of 28 cases 24 were males and 4 were females. 33 patients (55% of total patients) were having diabetes, out of them stenosis was present in 22 cases. So 66% diabetic patients showed carotid stenosis. Out of 22 cases 19 were males and 3 were females (Table 1).

Table 1: Association of hypertension, diabetes and hyperlipidemia with stenosis

<table>
<thead>
<tr>
<th></th>
<th>Stenosis present</th>
<th>Stenosis absent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (41)</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Absent (19)</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (33)</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Absent (27)</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (43)</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>Absent (17)</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Out of 60 ischemic stroke patients 25 patients have unilateral and 12 have bilateral carotid stenosis in CDUS. In CTA there are 26 patients have unilateral and 10 have bilateral carotid stenosis. In both modalities there are 7 arteries having multiple stenotic sites. So in total 120 arteries (60 patients) 49 are stenotic in CDUS and 46 are stenotic in CTA. In this study bulb was affected in 45% (22 out of 49).

The degree of stenosis as observed by both modalities was as follows. Stenosis 70-99% and occlusion almost match in both diagnostic methods, where as stenosis in 20-49% and 50-69% slightly differs. For 20-49% doppler detected 6 stenosis, out of them 3 lesions are detected as <20% (negligible) stenosis by CTA, which states the correlation between CDUS and CTA was not statistically significant (r=0.614, p=0.142). For 50-69% stenosis, 17 lesions were detected in CDUS and 13 lesions by CTA which states correlation was significant showing r=0.680 and p=0.011. In 70-90% and total occlusion group, % stenosis almost match (26 in CDUS and 29 in CTA) and correlation was statistically significant (r=0.805, p<0.01).

Table 2 and 3 shows correlation between CDUS% stenosis and CTA% stenosis of all categories together. The correlation was highly significant (r=0.90, p<0.01). Out of 60 stroke patients 49 (82%) patients have thickened carotid intima medi- thickness on ultrasonography (USG).

In this study, out of 49 plaques, 28 plaques are detected as Type-1 (echoluscent) and Type-2 (predominantly echoluscent) which states that echoluscent plaques have increased risk of becoming symptomatic. 26 plaques are heterogenous in morphology by USG, where as 19 plaques are heterogenous in CT. 23 plaques are found homogenous in USG. Heterogenous plaques have increased risk of becoming symptomatic. Carotid plaque surface ulceration is known as a strong predictor of future embolic stroke risk. Plaque ulceration is defined as an intimal defect larger than 1000µm in width, exposing thrombogenic layers of the plaque such as the necrotic core, with the possibility of a subsequent thrombus adhering to the plaque which further leads to embolization. In our study 16 ulcerative plaques were detected by doppler and 13 ulcerative plaques were detected by CTA in 37 stenotic patients. 23 plaques in USG and 18 plaques in CTA showed irregular surface which well correlate with the study. There are 9 calcified plaques noted in both types of investigation among total 49 plaques. Calcified dense plaques are more stable and there is less risk of becoming symptomatic.

**Discussion**

The word stroke implies brain cell death caused by infarction resulting in deficit enduring for days or longer. The deficit may be fleeting, in which case the cell death presumably does not occur. Such a brief episode is termed as Transient ischemic attack (TIA). For epidemiological reasons, focal neurological dysfunction of duration < 24 hours is termed as TIA. A longer lasting deficit with full recovery within three weeks is termed as Reversible ischemic neurological deficit (RIND). Treatment of stroke depends on reaching the earliest possible diagnosis possible through clinical and laboratory evaluation.
Table 2: Correlation of % stenosis by CDUS and CTA

<table>
<thead>
<tr>
<th>CDUS</th>
<th>CTA</th>
<th>20-49%</th>
<th>50-69%</th>
<th>70-99%</th>
<th>100%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal / &lt;20%</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>20-49%</td>
<td>0</td>
<td>1</td>
<td>13</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>50-69%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3</td>
<td>4</td>
<td>13</td>
<td>24</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3: Site and % stenosis correlation by CDUS and CTA

<table>
<thead>
<tr>
<th>Site</th>
<th>CDUS</th>
<th>CTA</th>
<th>100%</th>
<th>70-99%</th>
<th>50-69%</th>
<th>20-49%</th>
<th>100%</th>
<th>70-99%</th>
<th>50-69%</th>
<th>20-49%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCA</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BULB</td>
<td>1</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICA</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECA</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertebral</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Though angiography is the gold standard, it is invasive and immoderate and involves significant risk to the patients. Sonography is unique among vascular imaging procedures, in that it can assess plaque composition. Sonographically detected plaque characteristics may have prognostic value and may be useful for the selection of medical and surgical therapy.

Our present study consists of evaluating extra cranial carotid artery system in 60 patients with color doppler (CDUS) and contrast enhanced computed tomographic angiography (CTA). A study by Dae Suh et al considered 268 patients (219 male, 49 female; mean age 56 years) which was also consistent with our findings. The risk factors for cervical atherosclerosis was studied by Palomaki et al in patients with ischemic stroke and transient ischemic attack and found that incidence of stroke increases after 60 years of age. These findings also correlate well with Thomas et al and Mathiesen et al results wherein prevalence of and risk factors associated with carotid artery stenosis were also consistent with our findings.

In this study 70% (42 of 60) patients were males and 30% (18 of 60) patients were females. Lemolo et al in his study showed that majority of stroke victims were males.

68% of hypertensive patients show carotid stenosis and the findings correlated with Su et al study who studied the trends of carotid plaque formations by the status of blood pressure. About 53% of hypertensives were observed to have plaques while the corresponding values decreased to 41% for borderline hypertensives and to 34% for normotensives.

Studies found that the carotid bifurcation was commonly involved by the atherosclerotic plaque followed by the origin of carotid. Rubba et al also showed bulb as the most common site of plaque. In this study bulb was effected in 45% (22 out of 49).

The findings of study by Savic et al titled ‘Correlation of color doppler with multidetector CT angiography findings in carotid artery stenosis’ correlated well with our study.

Out of 60 stroke patients 49 (82%) patients have thickened carotid intima medial thickness (IMT) in USG. This finding correlates with Harris study, in which 259 patients, with age ranging from 31 to 75 years old, were divided into the stroke group (n=131) and non-stroke group (n=128). The author found abnormal IMT in both age groups, with an occurrence of 130 patients in the stroke group and 46 in non-stroke group.
Langsfeld et al\textsuperscript{15} studied 419 asymptomatic patients with atherosclerotic plaques for 15-22 months and found anechoic plaques more vulnerable to be at increased risk of stroke compared with dense and echogenic plaques (\(<\)0.02). In another study, O’Holleran et al followed 293 patients for an average of 46 months and showed that 100% of the patients with a soft lesion involving > 75% stenosis became symptomatic as compared with only 60% (\(>\)0.05) of those with a dense plaque\textsuperscript{16}.

Our study results were consistent with Sterpetti and colleagues, who found new neurological events occurring in 19 out of 71 carotid arteries (27%) with heterogenous plaques, where as only 6 carotid arteries out of 167 (4%) shows new events with homogenous plaques (\(<\)0.001).\textsuperscript{17} Sitzer et al\textsuperscript{18} showed that plaque ulceration and lumen thrombus are the main sources of cerebral microemboli in high-grade internal carotid artery stenosis.

In our study, 16 ulcerative plaques were detected by doppler and 13 ulcerative plaques were detected by CTA in 37 stenotic patients. 23 plaques in USG and 18 plaques in CTA showed irregular surface which correlated well with the study by Eliasziw et al\textsuperscript{19} who studied the association between angiographically defined plaque ulceration and risk of subsequent stroke in 659 patients with severe stenosis (70-99%) enrolled in North American Symptomatic Carotid Endarterectomy trial. The study shows that in unoperated patients with 85% stenosis due to ulcerated plaque the risk of ipsilateral stroke at 24 months is high (43.9%) in comparison to non ulcerated 85% carotid stenosis, the risk of ipsilateral stroke at 24 months was 21.3%. In patients with 95% carotid stenosis the 2-year risk of ipsilateral stroke was 73.2% in patients with ulcerated lesions and 21.3% in patients without evidence of ulcer (\(>\)0.005). This was also analyzed in the ECST trial\textsuperscript{20} which showed that stroke risk was increased among patients with irregular plaques for all degrees of stenosis, and that the association was also independent of other clinical and angiographical factors. In 1992, Steinke et al\textsuperscript{21} reported 63 patients with higher degree of stenosis in ultrasound and that ulcerated plaques were more frequently found among symptomatic (43%) than asymptomatic patients (23%).

In Zarei et al\textsuperscript{11} study stenosis of extracranial and intracranial arteries were detected in 38% and 29% of cases respectively. The extracranial stenosis was significantly more frequent than intracranial stenosis (\(<\)0.01). In this study out of 60 ischemic stroke patients, 22 patients had extracranial, 13 had intracranial, 14 had both extra and intracranial stenosis and 11 patients were without stenosis. This study also showed 39 stroke patients had collateral circulation detected in CTA and the collateral status is a useful predictor for clinical outcome in acute stroke patients.

**Conclusion**

The results of our study suggest that the combined use of CDUS and CTA is an acceptable method for quantification of severe carotid artery stenosis. CDUS is non-invasive, affordable, safe, reproducible, less time consuming and easily available method of demonstrating extra-cranial carotid artery system. It is more accurate in evaluation of plaque morphology. However it is relatively insensitive in stenosis quantification and not reliable diagnostic method in high set carotid bifurcation, heavily calcified arterial wall, short neck, obesity, presence of edema, scar after irradiation or when changes in the distal part of the artery are not available to ultrasound review, where MDCTA is advantageous. The accuracy of the ultrasound examination is strongly dependent on the skills of the examiner.

CTA with perfusion have become a choice of modality for accurate and prompt diagnosis of cause of cerebral ischemia. The site of arterial occlusion, percentage of stenosis of extracranial as well as intracranial carotid artery, length of occlusion and pattern of poorly perfused brain tissue and extent of collateral circulation can be better assessed by CTA which is operator independent.

**Acknowledgments:** None

**Conflict of interest:** None

**References**

6. Thomas GN, Lin JW, Lam WW, Tomlinson B, Yeung V, 
Chan JC, Liu R, Wong KS. Increasing severity of cardio-
vascular risk factors with increasing middle cerebral artery 
stenotic involvement in type 2 diabetic Chinese patients 
with asymptomatic cerebrovascular disease. Diabetes Care. 

7. Mathiesen EB, Joakimsen O, Bonaa KH. Prevalence of and 
risk factors associated with carotid artery stenosis: The 

8. Iemolo F, Martiniuk A, Steinman DA, Spence JD. Sex di-
ferences in carotid plaque and stenosis. Stroke 2004; 
35(2):477-481.

9. Su TC, Jeng JS, Chien KL, Sung FC, Hsu HC, Lee YT. 
Hypertension status is the major determinant of carotid ath-
erosclerosis: a community-based study in Taiwan. Stroke. 

10. Lacroix P, Aboyans V, Criqui MH, Bertin F, Bouhamed T, 
Archambeaud F, Laskar M. Type-2 diabetes and carotid 
stenosis: a proposal for a screening strategy in asympto-

cranial stenosis in patients with acute cerebrovascular ac-

12. Rubba P, Panico S, Bond MG, Covetti G, Celentano E, 
Iannuzzi R, Galasso R, Belisario MA, Pastinese A, 
Sacchetti L, Mancini M, Salvatore F. Site-specific athero-
sclerotic plaques in the carotid arteries of middle-aged 
women from Southern Italy. Associations with traditional 
risk factors and oxidation markers. Stroke. 2001; 

13. Savic ZN, Davidovic LB, Sagic DZ, Brajovic MD, Popovic 
SS. Correlation of color doppler with multidetector CT angi-
ography findings in carotid artery stenosis. Scientific World 

14. Harris S. The association of carotid intima-media thickness 
(cIMT) and stroke: A cross sectional study. Perspectives in 
Medicine 2012; 1(1-12):164-166.

15. Langsfeld M, Gray-Weale AC, Lusby RJ. The role of plaque 
morphology and diameter reduction in the development of 
new symptoms in asymptomatic carotid arteries. J Vasc 

Natural history of asymptomatic carotid plaque. Five year 

17. Sterpetti AV, Schultz RD, Feldhaus RJ, Davenport KL, 
Richardson M, Farina C, Hunter WJ. Ultrasonographic fea-
tures of carotid plaque and the risk of subsequent neuro-

18. Sitzer M, Muller W, Siebler M, Hort W, Kniemeyer HW, 
Jäncke L, Steinmetz H. Plaque ulceration and lumen 
thrombus are the main sources of cerebral microemboli in 
high-grade internal carotid artery stenosis. Stroke. 1995; 
26(7):1231-1233.

GG, Barnett HJ. Significance of plaque ulceration in symp-
tomatic patients with high grade carotid stenosis. North 
American Symptomatic Carotid Endarterectomy Trial. 

20. Rothwell PM. Carotid artery disease and the risk of ischemic 
stroke and coronary vascular events. Cerebrovasc Dis. 

21. Steinke W, Hennerici M, Rautenberg W, Mohr JP. Sympto-
matic and asymptomatic high-grade carotid stenoses in 
Doppler color-flow imaging. Neurology. 1992; 42(1):131- 
138.