Original Article

DOI: 10.17354/ijss/2016/05

Relevance of Color Doppler Study for the Assessment of Carotid Arteries of Individuals with Cerebrovascular Disease in Current Practice

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Abstract

Background: Stroke is a major cause of mortality and morbidity. Atherosclerosis of the cranial vessels leading to cerebral infarction accounts for 80% of strokes. Duplex sonography, combining high-resolution imaging and Doppler Spectrum analysis has provided to be popular, noninvasive, accurate, and cost-effective means of detecting and assessing carotid disease. Besides estimating the degree of stenosis, the biggest advantage of sonography is its ability to characterize plaque and identify plaques with a higher risk of embolization.

Aims and Objectives: (1) To evaluate the morphological changes that take place in an extracranial portion of carotid arteries by color Doppler of carotid arteries in patients with cerebrovascular insufficiency. (2) To assess the utility of peak systolic velocity ratio of internal carotid artery and common carotid artery in the quantification of the carotid arterial stenosis. (3) To evaluate the spectral pattern and the color flow pattern in hemodynamically significant carotid artery disease.

Materials and Methods: In this 5-year study, 200 patients who had clinical findings consistent with cerebrovascular insufficiency were selected, and color Doppler examination was done. Findings were recorded and compared with various velocity ratios. Statistical analyzes were made with IBM SPSS software version 20.0.

Results: As the age increased, % of area stenosis increased. As the degree of stenosis increased the various velocities and their respective ratios increased in proportion to the stenosis. The majority of the plaques were located in the carotid bulb, and most of them were hyperechoic.

Conclusion: Duplex ultrasonographic criteria showed a better correlation with actual stenosis when the intervals of the degree of stenosis were 0%, <50%, 50-70%, 70-99%, and 100%. Doppler ultrasound in carotid artery stenosis had a sensitivity of 88% and specificity of 84%.

Key words: Carotid artery plaque, Doppler duplex ultrasonography, Pulse wave analysis, Stenosis, Stroke

INTRODUCTION

Stroke or cerebrovascular disease is a major cause of death, ranking third behind only malignancies and cardiovascular disease. Atherosclerosis of the cranial vessels leading to cerebral infarction accounts for 80% of strokes. Intracranial hemorrhage and subarachnoid hemorrhage account for the remainder. It has been conclusively proven that the risk for major stroke is higher in the first 3 months after transient ischemic attack (TIA).[1-3] Accurate diagnosis of hemodynamically significant stenosis is critical to identify patients who would benefit from surgical intervention.[4-6]

Duplex sonography, combining high-resolution imaging and Doppler spectrum analysis has provided to be popular, non-invasive, accurate, and cost-effective means of detecting and quantifying carotid disease.[7,8] Carotid sonography has largely replaced angiography for suspected extracranial carotid atherosclerosis.[9,10] Besides estimating the degree of stenosis, the biggest advantage of sonography is its ability to characterize plaque and identify plaques with higher risk of embolization.[11-13] With high-resolution

Access this article online

www.ijss-sn.com

Month of Submission : 11-2015
Month of Peer Review : 12-2015
Month of Acceptance : 01-2016
Month of Publishing : 01-2016

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ultrasound, plaque can be characterized into relative risk groups for containing intraplaque hemorrhage which is thought by many to be precursor plaque ulceration.[14,15]

The aims of the study were: (i) To evaluate the morphological and physiological changes that takes place in extracranial portion of carotid arteries by color Doppler of carotid arteries in patients with cerebrovascular insufficiency, (ii) to assess the utility of peak systolic velocity (PSV) ratio of internal carotid artery (ICA) and common carotid artery (CCA) in quantification of the carotid arterial stenosis, and (iii) to evaluate the spectral pattern and the color flow pattern in hemodynamically significant carotid artery disease by Duplex sonography.

MATERIALS AND METHODS

This study was carried out in the Department of Radiology in Rajah Muthiah Medical College and Hospital between October 2010 and September 2012 and in the Department of Radiology in Chettinad Hospital and Research Institute between October 2012 and September 2015. Sonographic examination of carotid arteries was done using Philips EnVisor Version C.0.2 machine with the multi-transducer system using a high frequency 7 MHz color Doppler linear array transducer. The examination was performed with a Doppler angle of 60°.

200 cases referred to the Radiology Department with history, and clinical findings consistent with cerebrovascular insufficiency for Color Doppler of carotid arteries were included in the study. The following data were collected:

- Intima-medial thickness (IMT) of CCA
- PSV of CCA and ICA
- PSV ratio between ICA and CCA
- Plaque characterization on real-time image
- Measurement of vessel lumen from frozen real-time image
- The presence of spectral broadening or turbulence.

The normal Intima-media thickness is <0.8 mm in healthy individuals.[16] As the study was conducted on 200 patients and each one has two carotid arterial systems, the analysis could be considered on the basis of 400 arteries. This made the calculations and observations easier as in some patients the IMT values were different on two sides.

An artery was classified as being affected by plaque if a focal thickening of >1.2 mm was observed in the vessel wall. Each major plaque was considered as a single entity. Therefore, any vessel showing 2 or more such plaques in tandem were considered as separate entities, whereas multiple insignificant small plaques seen in continuity and having a similar morphological appearance on gray scale ultrasonography were considered as a single entity. Statistical analyzes were made with IBM SPSS software version 20.0.

OBSERVATION AND RESULTS

The age of the patients ranged from 35 to 85 years. Out of total 200 patients, 112 were males and 88 females. The maximum number of patients belonged to the age group of 60-69 years, both in case of males (44) and females (36) making a total of 80 out of 100 patients, i.e., 40% of the total. The patients most commonly had TIA (62) followed by Hemiplegia/Hemiparesis (46) and coronary artery disease (30). Other complaints included Amaurosis fugax, vertigo, memory impairment, and confusion.

Six patients had velocities of their carotid arteries in higher ranges suggesting stenosis but no plaque was found in them. Four of them were found to have hyperthyroidism.

The mean age of patients with their arteries free of any plaques or stenosis was 57.04 ± 13.79 years and that of patients showing any evidence of plaques on either or both sides was 63.54 ± 10.72 years. This difference was statistically significant ($P < 0.05$).

20, out of a total of 400, arteries showed complete occlusion. Out of all the arteries in female patients, 104 arteries had 0% stenosis and only 4 had 100% stenosis (Figure 1). Stenosis increased PSV (Figure 2). In male patients, 32 arteries were found to have 100% stenosis, and 152 had 0% stenosis. Male:female ratio in stenosed arteries was 2:1. Females:males ratio was 3:2 for arteries free of any plaque or stenosis. The duplex criteria in relation with directly observed stenosis are illustrated in Table 1.

Out of total 200 arteries, 144 arteries had their IMT within normal limits and 56 above it. In patients who were <60 years of age only 4 arteries out of 74 had IMT

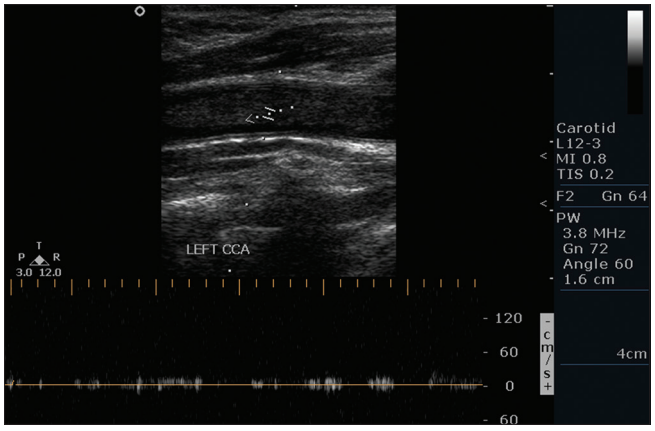

Figure 1: Left common carotid artery occlusion with absence of spectral wave

Table 1: Duplex criteria in relation with directly observed stenosis

% area of stenosis	No. of patients	ICA PSV Cm/sec	ICA EDV Cm/sec	ICA PSV/ CCA PSV	ICA EDV/ CCA EDV	ICA PSV/ CCA EDV
0	92	60.1	26.9	0.85	1.13	2.81
<30	50	69.2	21.6	0.94	1.23	4.20
30-39.9	8	57.95	19.8	0.95	1.48	4-49
40-49.9	16	80.85	26.2	0.90	1.38	4.16
50-59.9	4	127.3	17.05	2.11	1.08	7.98
60-69.9	12	127.5	17.05	2.11	1.08	7.98
70-79.9	4	192.95	31.15	1.53	2.2	7.11
80-89.9	2	389	104	3.74	5.87	21.97
90-99.9	2	282	159	3.55	8.5	15.08
100	Nil	Nil	Nil	Nil	Nil	Nil

EDV: End diastolic velocity, CCA: Common carotid artery, PSV: Peak systolic velocity, ICA: Internal carotid artery

>0.8 mm, whereas in patients >60 years it was 46 out of 124 arteries. Four patients of 80-90 years had their IMT <0.8 mm. The age group of 60-69 had a maximum number of arteries, i.e., 14 which had IMT >0.8 mm.

Out of the total 400 arteries examined 220 plaques were found (Table 2). Plaques were classified in relation to the arterial wall and were labeled as hypoechoic, hyperechoic (Figures 3 and 4), and calcified (Figure 5). 54 out of 220 (26.36%) plaques were hypoechoic, 130 (55.45%) were hyperechoic. The rest were calcified. Plaques with surface irregularity were observed in 58 out of 220 (9.33%). Remaining 130 (60%) were smooth. 16 plaques out of 220 (7.2%) had well-defined hypoechoic areas within them, suggestive of intra plaque hemorrhage.

Out of the total 220 plaques, 100 (45.45%) were located in the region of the bulb, 68 (30.91%) in ICA and 48 (21.82%) in the CCA. Some of the plaques in the region of carotid bulb were seen extending into ICA and external carotid artery (ECA). The location of such plaques was included in the "Bulb" category. Only 4 (2.2%) plaques were seen in ECA, which were separate from the plaque involving the bulb and were considered as a separate entity.

Table 2: Plaque characteristics

Appearance	Hypoechoic	Hyperechoic	Calcified	Total	% age
Smooth	30	70	30	130	71.5
Irregular	24	20	14	58	31.9
Ulcerated	0	32	0	32	17.6
Total	54	122	44	220	100
% age	29.7	67.1	24.2	100	

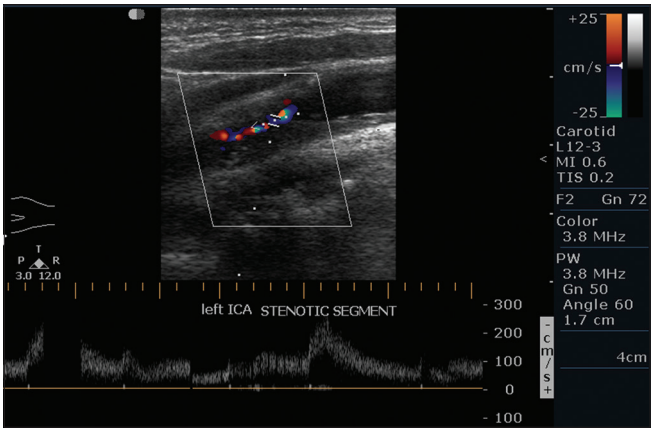

Figure 2: Narrowing of left internal carotid artery showing increased velocity

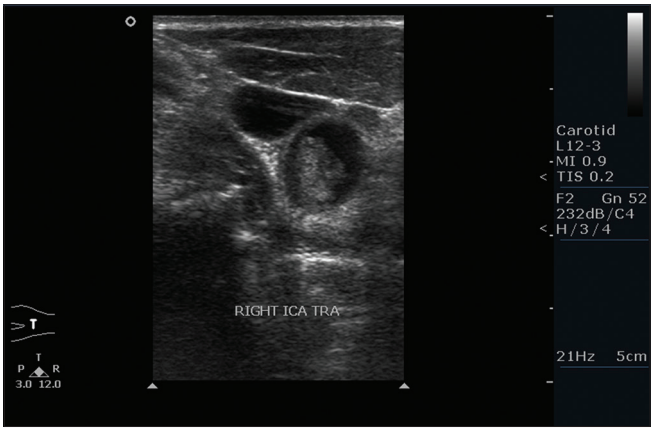

Figure 3: Cross-sectional view of the right internal carotid artery showing eccentric echogenic plaque involving 50% diameter

DISCUSSION

In our study, a maximum number of patients belonged to the age group of 60-69 years. As the age increased, % of area stenosis increased.

The mean IMT both on the right and left side were higher in males than that in females for the age groups, and the mean IMT on the left side was higher than that on the right side. However, these differences were not statistically significant ($P > 0.05$) and may be accounted for by the small number of subjects in our study.

As the degree of stenosis increased the various velocities and their respective ratios (ICA PSV/CCA PSV; ICA end diastolic velocity (EDV)/CCA EDV and ICA PSV/CCA

EDV) increased in proportion to the stenosis, suggesting a positive correlation between them (Table 3). The majority of the plaques were located in the region of carotid bulb, and most of them were hyperechoic.

Duplex ultrasonographic criteria showed a better correlation with actual stenosis when the intervals of the degree of stenosis were 0%, <50%, 50-70%, 70-99%, and 100%. Trying to quantify the stenosis in 10° incremental intervals was particularly inadequate and less sensitive and specific. In our study, Doppler ultrasound in carotid artery stenosis had a sensitivity of 88% and specificity of 84%.

Figure 4: Echogenic plaque in right internal carotid artery delineated by color Doppler

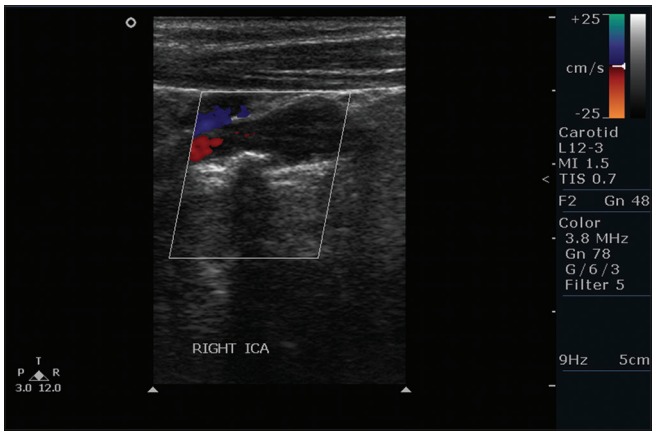

Figure 5: Heavily calcified plaque in right internal carotid artery

Table 3: Relation between degree of stenosis, various velocities and ICA/CCA ratio

Degree of stenosis %	ICA PSV cm/sec	ICA EDV cm/sec	ICA PSV/ CCA PSV
<50	<127.5	<40	<2.1
>80	>282	>104	>3.55

EDV: End diastolic velocity, CCA: Common carotid artery, PSV: Peak systolic velocity, ICA: Internal carotid artery

CONCLUSION

In light of the above findings, the role of carotid Doppler in detecting the site and morphology of atherosclerotic plaque with quantifying the amount of stenosis is very well-justified. In addition, carotid Doppler can also be used to assess the prognosis in potential symptomatic and asymptomatic patients with one or the other risk factor for cerebrovascular disease.

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How to cite this article: Einstien A, Kumar NP. Relevance of Color Doppler Study for the Assessment of Carotid Arteries of Individuals with Cerebrovascular Disease in Current Practice. Int J Sci Stud 2016;3(10):23-26.

Source of Support: Nil, **Conflict of Interest:** None declared.