Color Doppler Evaluation of Carotid Arteries in Cerebral Ischemia

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ABSTRACT

Introduction: Early detection of atheromatous changes in the carotid vessels would help to prevent the morbidity and mortality due to ischemic stroke. Doppler sonography incorporated in duplex system is reported to be highly accurate relative to angiography for the detection and classification of the degree of obstruction. 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. Study aimed to assess the role of color Doppler in evaluating cervical carotid arteries among patients with cerebral ischemia.

Material and methods: A cross-sectional observational study was conducted for a period of one and half years in a tertiary care hospital in Salem. Patients with increased risk of cerebrovascular diseases in the age group between 40 and 90 years were included in the study. Quota type of sampling method was followed to select 50 patients as our study participants and in that 40 were symptomatic (cases) either with stroke or TIA and the remaining 10 was asymptomatic which is considered as a control group. Colour Doppler was performed on all study subjects using GE LOGIC P5 sonography system with a high frequency 7MHZ linear array electronic transducer. Measurement of the vessel lumen was done from frozen real time images.

Results: Percentage of vessel stenosis based on PS velocity ratio ICA/CCA among the ischemic stroke patients showed that 45% of them had more than 40% stenosis and in controls it is only 30%, more than 80% occlusion was seen in 2.5% of the subjects among cases and 5% of them had total occlusion whereas none of them in control group had more than 60% occlusion and the difference was found to be statistically significant. Most of the plaque identified in our study was calcified plaque and nearly 28% showed homogenous hypoechoic and 27% showed heterogenous pattern that which indicates the severity of stenosis.

Conclusion: Carotid colour Doppler is an economical, safe, reproducible and less time consuming method for demonstrating lesion in carotid arterial system.

Keywords: Carotid Color Doppler, Peak Systolic Velocity Ratio, Atheromatous Plaques.

INTRODUCTION

Cerebral ischemia is defined as the focal neurological deficit lasting for more than 24 hours which is sudden in onset and its long lasting nature of more than 24 hours differentiates it from transient ischemic attack.[1] Of all causes of mortality in adults cerebral ischemia ranks third. The most common site of thromboembolic event in cerebral ischemia is the carotid artery plaque rupture due to atherosclerosis. Early detection of atheromatous changes in the carotid vessels would help to prevent the morbidity and mortality due to ischemic stroke. There were various sonographic techniques that have been used for the assessment of carotid arteries during a cerebrovascular event.[2] Of all these, continuous-wave Doppler and single-gate pulsed-wave Doppler sonography incorporated in duplex systems are reported to be highly accurate relative to angiography for the detection and classification of the degree of obstruction producing a narrowing of lumen more than 50%.[3]

The plaques are generally visualised as echogenic, hypoechoic or calcified lesions sometimes associated with intraplaque haemorrhage and surface ulceration and it also predicts the percentage of stenosis. Doppler parameters such as pulsatility index (PI), resistive index (RI) and systolic-diastolic ratio were used to evaluate and classify obstructive changes and occlusive diseases of the carotids.[4-8] 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.[4-6] With high resolution ultrasound, plaque can be characterized into relative risk groups for containing intraplaque hemorrhage which is thought by many to be precursor plaque ulceration.[7,8]

Various studies had also shown that the reproducibility of this method is very high and the results obtained by it are almost in par with the results of arteriography. As of today only very few studies have been conducted to assess the role of Doppler in evaluating the carotid arteries among patients presenting with cerebral ischemia and so the present study was conducted to assess the role of carotid Doppler among cerebral ischemia patients.

Study aimed to assess the role of color Doppler in evaluating cervical carotid arteries among patients with cerebral ischemia.

MATERIAL AND METHODS

A cross-sectional observational study was conducted for a period of one and half years in a tertiary care hospital in Salem. The study was started after getting approval from the institutional ethical committee and the informed consent was obtained from all the study participants involved in the study. Patients with increased risk of cerebrovascular diseases in the age group between 40 and 90 years were included in the study. Quota type of sampling method was followed to select 50 patients as our study participants and in that 40 were symptomatic (cases) either with stroke or TIA and the remaining 10 was asymptomatic which is considered as a control group. A semi-structured questionnaire was designed and a detailed clinical history and neurological examination was conducted and the findings were recorded. Risk factors related to stroke or TIA such as history of diabetes, hypertension, smoking and ischemic heart diseases was also enquired and documented.

Colour Doppler was performed on all study subjects using GE LOGIC P5 sonography system with a high frequency 7MHZ linear array electronic transducer. Measurement of the vessel lumen was done from frozen real time images. The following are the data gathered from color Doppler

- Peak systolic velocity of common carotid artery
- Peak systolic velocity of internal carotid artery
- Velocity ratios between internal carotid artery and common carotid artery (ICA/CCA)
- Measurement of area of stenosis of vessel lumen
- Plaque characteristics
- Presence of spectral broadening or turbulence

The factors evaluated on color flow are
- Width of the lumen
- Degree of turbulence as evidenced by mosaic pattern
- Pulse repetition frequency

All data were entered and analysed using SPSS version 24. Mean and standard deviation was calculated for all the parametric variables and percentage was calculated for all frequency variables and statistical inference was drawn by applying chi-square test.

RESULTS

The age wise distribution of the study subjects shows that the minimum age was 40 and the maximum is 82 years with a mean age of 57 among males and 54 among females. Males were comparatively more in number than females in both cases and controls. Majority of the cases with ischemic stroke were in the age group between 50 and 70 years (table 1). Among the ischemic stroke patients the common risk factors identified were smoking, diabetes and hypertension and almost all patients had either one or multiple risk factors whereas among the controls these risk factors were very minimal and the difference was found to be statistically significant (table 2). The site of atheromatous plaque distribution was mostly unilateral and only 20% of the population had bilateral involvement and the most common area of involvement was carotid bifurcation followed by common carotid, internal

Age group	Cases (n=40)		Controls (n=10)		P value
	Males	Females	Males	Females	
40 – 50	4 (13.3%)	2 (20%)	1 (12.5%)	1 (50%)	0.319
51 – 60	12 (40%)	2 (20%)	3 (37.5%)	0	
61 – 70	9 (30%)	3 (30%)	3 (37.5%)	0	
71 – 80	3 (10%)	2 (20%)	1 (12.5%)	1 (50%)	
>80	2 (6.6%)	1 (10%)	0	0	
Mean ± SD	57.4 ± 7.8	54.2 ± 8.9	52.8 ± 9.1	62.4 ± 15.2	
Total	30 (100%)	10 (100%)	8 (100%)	2 (100%)	
P value derived by applying chi-square test					

Table-1: Age and gender wise distribution of the study subjects

Risk factors	Cases (n=40)	Controls (n=10)	P value
Smoking	27 (67.5%)	3 (30%)	<.001
Hypertension	30 (75%)	4 (40%)	<.001
Diabetes	24 (60%)	2 (20%)	<.001
P value derived by applying chi-square test			

Table-2: Distribution of the study subjects based on presence of risk factors

Arteries	Right	Left	Bilateral
Carotid bifurcation	5 (33.3%)	7 (41.1%)	2 (25%)
Common carotid	4 (26.6%)	6 (35.2%)	1 (12.5%)
Internal carotid artery	4 (26.6%)	1 (5.8%)	5 (62.5%)
External carotid artery	2 (13.3%)	3 (17.6%)	0
Total	15 (100%)	17 (100%)	8 (100%)

Table-3: Distribution of the study subjects (cases) based on the site of atheromatous plaque distribution

carotid and external carotid artery (table 3). Most of the plaque identified in our study was calcified plaque and nearly 28% showed homogenous hypoechoic and 27% showed heterogenous pattern that which indicates the severity of

Figure-1: Carotid intima media thickening

Figure-2: Plaque in common carotid artery

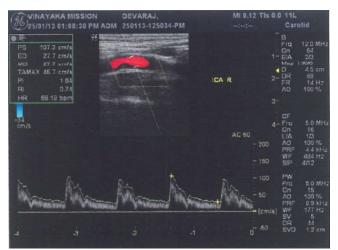| Plaque characteristic	Frequency	Percentage
Calcified plaque	18	45%
Homogenous hypoechoic	11	27.5%
Heterogenous hyperechoic	7	17.5%
Heterogenous	4	10%
Total	40	100%
Table-4: Distribution of the study subjects based on the characteristics of the plaque identified		

Figure-3: Internal carotid artery stenosis longitudinal view

Figure-4: Transverse view of carotid artery stenosis >60%

Figure-5: Calcified plaques

Percentage of vessel stenosis	PS velocity ratio ICA/CCA	Cases	Controls	P value
0 – 40 %	<1.5	22 (55%)	7 (70%)	<.001
41 – 60%	>1.5 – 1.8	9 (22.5%)	3 (30%)	
61 – 80%	>1.8 – 2.5	6 (15%)	0	
81 – 90%	>2.5	1 (2.5%)	0	
Complete occlusion		2 (5%)	0	
Total		40 (100%)	10 (100%)	
P value derived by applying chi-square test				
Table-5: Distribution of the study subjects based on the vessel stenosis and PS velocity ratio ICA/CCA				

stenosis (table 4). Percentage of vessel stenosis based on PS velocity ratio ICA/CCA among the ischemic stroke patients showed that 45% of them had more than 40% stenosis and in controls it is only 30%, more than 80% occlusion was seen in 2.5% of the subjects among cases and 5% of them had total occlusion whereas none of them in control group had more than 60% occlusion and the difference was found to be statistically significant (table 5). Various features of carotid Doppler are shown in fig 1 – 5.

DISCUSSION

Life of a person is dramatically affected by an episode of stroke either in the form of disability or death. Also the direct and indirect cost that is spent during the illness is huge. In India as per the data 5% of the people above 65 years are affected by stroke. The present study was conducted to evaluate the extra-cranial arterial system among the patients presented with cerebrovascular insufficiency and comparing them with asymptomatic patients. Two RCT's done in North America and Europe had clearly reported that endarterectomy is highly beneficial for patients having more than 70% of carotid stenosis and in the same study it had also proven that there is no benefit of conducting endarterectomy when the stenosis is less than 30%.[11,12] Another randomized trial done by Joseph.K.Polak showed a distinct advantage of endarterectomy among asymptomatic patients who had had 60% of carotid stenosis. So assessing the carotid vessels for people aged more than 60 years with any risk factors for stroke by using carotid Doppler would have a beneficial role in reducing the morbidity and mortality due to stroke.[13]

In the present study majority of the patients having carotid artery disease were in the age group between 61 and 70 years and it is almost similar to the study conducted by Sanguigni V etal.[14] A recent study done in the year 2016 in Tamil Nadu had also quoted people in the age group of 60 to 69 are most commonly affected by stroke.[15] In our study we found men are more commonly affected than the females as they are more prone for atherosclerosis which can be explained on the basis of the protective female hormones mainly the estrogens and the progesterones but the risk become almost similar after their menopause and a similar type of results was also shown in a study done by S K Sethi etal.[16]

Smoking causes a reduction of HDL levels and promotes fibrinogenemia.[17] Hypertension produces a continuous trauma to endothelium and predisposes to the early stage of atherogenesis. The advanced stages of atherosclerosis might lead onto plaque formation.[18] Many studies done earlier had clearly mentioned that a raised systolic and diastolic blood pressure and patients taking antihypertensives for a longer duration were more prone to develop ischemic stroke.[19] Wolfe et al using the Framingham study cohort found Mean systolic blood pressure to be 139.3mm Hg in males and 142.8mm Hg in females among the patients reported with stroke.[20] Dhamija et al in his study not only concluded quoting hypertension is a consistent risk factor for ischemic stroke but also mentioned that patients with high systolic blood pressure are more prone to develop stroke than the diastolic pressure.[21] Few studies have also mentioned Diabetes mellitus as a significant risk factor for developing stroke.[22]

Incidence of stroke in diabetics has been found to be 2 to 3 times higher than in general population.[23] In our study we found smoking, hypertension and diabetes is present among majority of the patients presented with ischemic stroke.

In a study done by Erickson S J etal in which he compared the carotid Doppler parameters with carotid angiography and he found that in carotid Doppler B-mode measurement is most accurate when the vessel stenosis is less than 40% whereas the ratio of ICA/CCA was found to be the most accurate parameter for patients with stenosis more than 70%.[24] In our study we observed 18 out of 40 symptomatic patients had more than 40% stenosis and the remaining 22 patients had less than 40% stenosis. In all the 22 patients peak systolic velocity is less than 120 cm/s and so in these patients PSV cannot be used to subquantify and it is almost similar to the results quoted by Erickson S J etal.[24]

Among the 10 asymptomatic patients the prevalence of the disease in the extra-cranial carotid arterial system was seen in 4 patients and all those 4 patients had more than 40% stenosis as determined by peak systolic velocity ratio ICA/CCA.

Zwiebel W J has classified the plaques as low echogenicity plaques, moderately echogenicity plaques, strongly echogenicity plaques, calcified plaque with acoustic shadowing.[25] In our study atheromatous plaques of 40 patients are of different size and extent and we classified the plaque characteristics as described by J F Polak and based on that calcified plaques were seen in 18 patients; homogenous hypoechoic was seen in 11 patients; heterogenous hyperechoic in 7 patients and heterogenous lesion was observed in 4 patients.[26]

In the current study bifurcation of common carotid artery is the commonest source in the extracranial carotid artery atherosclerosis which is in accordance with Philips etal.[27] In our study most of the symptomatic patients had either focal or diffuse non-homogenous plaque due to thrombus formation and they are more at risk of developing intra-plaque hemorrhage as mentioned in the study done by Reilly L M etal and Lusby etal.[28,29]

A study done by Granth EG etal had proved that PSV ratio is a better predictor for stenosis compared to isolated PSV to ICA[30] and in our study also it is very much proven as PSV ratio <1.5 is equivalent to stenosis less than 40%, PSV ratio between 1.5 and 2.5 the level of stenosis is between 40 and 80% and PSV ratio more than 2.5 indicates that the stenosis is more than 80%.

According to Taylor etal carotid Doppler sonography has 99% sensitivity and 84% specificity in detecting carotid stenosis in comparison with carotid angiography.[31] But in our study this comparison was not done as majority of the patients were not subjected to angiogram due to logistic issues.

CONCLUSION

Colour Doppler sonography is a non-invasive, easily available and re-producible in the valuation of extracranial carotid artery. It helps in delineating lesions that are difficult to see on grey scale imaging thus facilitating detection of low echogenic plaques. It also helps in better characterization of the carotid plaques with associated flow abnormalities.

It is therefore concluded that carotid colour Doppler is an economical, safe, reproducible and less time consuming method for demonstrating lesion in carotid arterial system.

REFERENCES

1. Bhatti TS, Harradine KL, Davies B, Earnshaw JJ, Heather BP. Urgent carotid endarterectomy can reduce the risk of stroke after a TIA. Br J Surg 1999;86(1):699.

2. Donnan GA, Fisher M, Macleod M, Davis SM. Stroke. Lancet. 2008;371(9624):1612-23.

3. Steinke W, Kloetzsch C, Hennerici M. Carotid artery disease assessed by colour Doppler fl ow imaging: Correlation with standard Doppler sonography and angiography. AJR Am J Roentgenol 1990;154(5):1061-8.

4. Cooperberg E. Ultrasound Doppler spectral analysis in the diagnosis of occlusive lesions of the carotid arteries. Ultrasound Med Biol 1992;18(6):421-5.

5. Whyman MR, Naylor AR, Ruckley CV, Wildsmith JA. Extracranial carotid artery flow measurement during carotid endarterectomy using a Doppler ultrasonographic flowmeter. Br J Surg 1994;81(1):532-5.

6. Planiol T, Pourcelot L, Pottier JM, Degiovanni E. Study of carotid circulation by means of ultrasonic methods and thermography. Rev Neurol (Paris) 1972;126(3):127-41.

7. Archie JP Jr. A simple, non-dimensional, normalized common carotid Doppler velocity wave-form index that identifies patients with carotid stenosis. Stroke 1981;12(5):322-4.

8. Babiker MS. The effects of smoking on carotid artery hemodynamics. J Diagn Med Sonogr 2016;32(1):149-50.

9. You RX, Thrift AG, McNeil JJ, Davis SM, Donnan GA. Ischemic stroke risk and passive exposure to spouses' cigarette smoking. Melbourne Stroke Risk Factor Study (MERFS) Group. Am J Public Health 1999;89(4):572-5.

10. Lee EJ, Kim HJ, Bae JM, Kim JC, Han HJ, Park CS, et al. Relevance of common carotid intima-media thickness and carotid plaque as risk factors for ischemic stroke in patients with type 2 diabetes mellitus. AJNR Am J Neuroradiol 2007;28(2):916-9.

11. Gary G. Ferguson, Michael Eliasziw, Hugh W. K. Barr, G. Patrick Clagett. The North American Symptomatic Carotid Endarterectomy Trial. Stroke. 1999;30(9):1751-1758.

12. N.Rudarakanchana, M. Dialynas, A. Halliday. Asymptomatic Carotid Surgery Trial-2 (ACST-2): Rationale for a Randomised Clinical Trial Comparing Carotid Endarterectomy with Carotid Artery Stenting in Patients with Asymptomatic Carotid Artery Stenosis. European Journal of Vascular and Endovascular Surgery. 2009;38(2):239-242.

13. Joseph K Polak, John S Pellerito. Introduction to vascular ultrasonography. Seventh edition; 2012, Elsevier, Philadelphia.

14. Sanguigni V, Gallù M, Strano A. Incidence of carotid artery atherosclerosis in patients with coronary artery disease. Angiology. 1993;44(1):34-8.

15. Alagesan Murali, Anith Kumar Mambatta, R.R.M. Ranganathan. Comparison of Carotid Intima Media Thickness in Children of Patients with and without Premature Coronary Artery Disease. Journal of Clinical and Diagnostic Research. 2016;10(12): OC29-OC31

16. SK Sethi, RS Solanki, H Gupta. Color And Duplex Doppler Imaging Evaluation Of Extracranial Carotid Artery In Patients Presenting With Transient Ischaemic Attack And Stroke- A Clinical And Radiological Correlation. Ind J Radiol Imag 2005 15:1:91-98

17. O'Donnell MJ, Xavier D, Liu L, Zhang H, Chin SL, Rao-Melacini P, et al. Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): a casecontrol study. Lancet. 2010;376(9735):112-23.

18. Garg S, Kashikar SV, Phatak S. Colour doppler evaluation of extracranial carotid arteries: a clinical and radiological correlation. Journal of Clinical and Diagnostic Research. 2016;10(1):TC06-TC10.

19. Ellekjaer EP, Wyller TB, Sverve JM, Holmen J. Life style factors and risk of cerebral infarction.Stroke. 1992; 23(6): 829-83

20. Wolf PA, D'Agostino RB, Bilanger AJ, Hannel WB. Probability of stroke- A risk profile from the Framingham heart study. Stroke. 1991; 22(1):312-318.

21. Dhamija RK, Dhamija SB. Prevalence of stroke in the rural community-An overview of Indian expeience. JAPI. 1998; 46(4): 351-354.

22. Duncan GW, Slees R, Ojemann RG, David SS. Concominants of atherosclerotic carotid artery stenosis. Stroke. 1977;8(6): 665-668.

23. Kistler JP, Roppert AH, Martin JB. Cerebrovascular disease. In Harrisons principles of internal medicine 1994; 13th edition: 2233-2256.

24. J Erickson, D Middleton, Dennis Foley etal. Color Doppler evaluation of arterial stenoses and occlusions involving the neck and thoracic inlet. Radiographics.1989;9(3):389-93.

25. Zweibel WJ. Introduction to Vascular Ultrasonography. 4th ed. Philadelphia: W.B. Saunders Company; 2000. Physics and instrumentation in Doppler and mode ultrasonography; Ch.2 pp. 17–27.

26. Polak JF. Carotid ultrasound. Radiol Clin North Am 2001;39(4):569-89.

27. Philips DJ, Green FM. Flow velocities in carotid bifurcation of young presumed normal subjects. Ultrasound Med.Biol. 1983 9(6):39.

28. Reilly LM. Importance of carotid plaque morphology. 1983;In Bernstein EF (ed).,Vascular diagnosis 4th edition.ST. Louis, Mosby-Year book; p 333-40.

29. Lusby RJ, Ferrel L D, Ehrlenfeld WK. Carotid plaque hemorrhage. Arch Surg. 1981;117(1):1479-87.

30. Grant EG, Wong W, Tessler F, Perrella R. Cerebrovascular ultrasound imaging. Radiol Clin North Am. 1988;26(5):1111-30.

31. Taylor DC, Strandness DE Jr. Carotid artery duplex scanning. J Clin Ultrasound. 1987;15(9):635-44.