Original Research Paper Medical Science

Carotid Doppler in Patients of Stroke

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ABSTRACT

Cerebrovascular accident is a neurological emergency with the cases of stroke accounting for approximately 9 to 30% of all the neurological admissions. Trans-cranial Doppler and Carotid Doppler imaging play an important role in the study of flow parameters in the intracranial and extracranial blood vessels respectively. Plaque characteristics and percentage stenosis can be detected. Ultrasound of extra-cranial cerebral circulation is used predominantly in assessment of patients with symptoms, which might arise from disease in carotid arteries. Computed tomography was carried out in 100 patients clinically suspected of having stroke. Carotid Doppler was carried out in all the patients diagnosed of having stroke or normal (but had signs and symptoms of Stroke) on computed tomography. We found that Doppler Ultrasound is an easy , readily available , cost effective technique with good technical efficiency. Atherosclerotic plaques are a common lesion in patients of stroke. Hypoechoic plaques have a great predictive value for development of large vessel stroke. Severity of stenosis of the extra cranial carotid Doppler has significant association with large vessel infarcts and has no association with lacunar infarcts and Hemorrhagic stroke, the etiology of which could some thing different. Thus every patient presenting with cerebrovascular symptom must undergo complete color duplex US examination of the carotid arteries, this will guide in selection of treatment modalities and will help in assessing the follow up of the disease and evaluating the effectiveness of treatment.

KEYWORDS :Stroke , Carotid Doppler , Ischemic Stroke

INTRODUCTION

Recent advances in computed tomography, magnetic resonance imaging, MRA and color Doppler, have brought us in an era of noninvasive assessment of the brain and its vessels.

The technology of producing ultrasound and the characteristics of sonic waves has been known for many years. However its practical applications were made after World War II, in the form of SONAR (Sound Navigation And Ranging) for the search of ships.

Developments in Doppler ultrasound were being made along with B-mode ultrasound, but the fusion of the two in duplex scan and subsequent development of color Doppler imaging provided more scope for investigating the circulation and blood supply to organs.

Ultrasound of extra-cranial cerebral circulation is used predominantly in assessment of patients with symptoms, which might arise from disease in carotid arteries. In addition their examination could also provide a method for assessing the rate of progression or regression of disease, if treatment regimes are being investigated or epidemiological studies are being performed. With increasing sensitivity and specificity and accurate technique, it is becoming effective screening modality for patients with hemodynamically significant disease prior to surgery or instituting medical therapy.

In this prospective study of 100 patients referred to our department with clinical diagnosis of stroke Carotid Doppler was carried out in all the patients diagnosed of having stroke or normal (but had signs and symptoms of Stroke) on computed tomography. Stroke mimics presenting clinically as stroke were excluded after the computed tomography result. Our aim was to find the association between nature (ischemic / hemorrhagic), extent (large / small) of the stroke with the nature and extent of carotid vessel disease.

MATERIAL AND METHODS

Our study was carried out in Dr D Y Patil Medical College and Hospital . Color Doppler – Aloka . High frequency Linear probe 7.5 MHz (variable frequency 6 to 10 MHz) was used to perform color doppler examination of the cervical carotid vessels. Patient Selection-In this study, 100 patients, presenting as CVA, referred from the department of medicine and outside were studied. They were evaluated for any intracranial pathology with the help of computed tomography. The patients in whom Computed Tomography (CT) appearances of the lesions were proved to be due to cerebrovascular accident or which were normal but had obvious signs of neurological deficit, underwent Carotid Doppler .

On Computed Tomography (CT)the findings the patients were classified as - **Group A** – Patients with Large vessel infarct, **Group B** – Patients with Small vessel / lacunar infarct - **Group C** - Patients with Primary non-traumatic Intra-cerebral / subarachnoid / Intra-ventricular Bleed, **Group D** – Diagnosis other than Group A, B & C eg. SOL , abscess , Subdural hemorrhage etc., **Group N** – CT findings were normal. The group N patients were interpreted as TIA or could be stroke in evolution (on basis of clinical findings of obvious neurological deficit) in acute stage where the CT could be normal.

Doppler Study - Doppler study was done in all the patients who were on CT diagnosed to have stroke irrespective of the type of stroke or those whom CT was normal i.e the patients who had clinical signs and symptoms of stroke but CT normal who were concluded to have TIA or were in acute stage/ stroke in evolution).

All the patients were scanned for both right and left CCA (Common carotid artery) , ICA (Internal carotid artery) , ECA (external carotid artery) and VA (vertebral artery) on B-mode, color mode and spectral

wave features but for calculations and to establish correlation with CT findings, Doppler parameters of only the affected side was considered . In case of normal patients the side of clinical suspicion of stroke was considered. In case of midline lesions as brain-stem hemorrhage the side with greater luminal occlusion was considered for calculations.

Also Carotid Doppler study was done on 30 control random patients who were of age more than 50 and who did not have clinical evidence or past history of stroke. Only the right carotid study was done in the control group.

Bilateral carotid vessels studied but only one ipsilateral to the side of lesion taken into consideration in observations.

Written consent was obtained from the patients to be included in the study.

OBSERVATIONS-

1. Table showing degree of stenosis seen in symptomatic patients

Degree of stenosis	Normal	1-29%	30-49%	50-70%	71-99%
Large Infarcts	3	2	3	14	4
Percentage (%)	11.53	7.69	11.53	53.84	15.38
Lacunar infarcts	4	6	4	2	-
Percentage (%)	25	37.5	25	12.5	-
Hemorrhage	15	7	3	1	-
Percentage (%)	57.53	26.92	11.53	3.84	
Normal	5	2	7	9	-
Percentage (%)	21.73	8.69	30.43	39.13	-
Controls	18	7	-	5	-
Percentage	60.00	23.33	-	16.66	-

2.Table showing plaque characteristics as seen on US in patients.

Type of Plaque	Normal	Type I	Type II	Type III	Type IV
Large Infarcts	1	-	17	7	1
Percentage (%)	3.84	-	65.38	26.92	3.84
Lacunar infarcts	4	-	4	7	1
Percentage (%)	25	-	25	43.75	1.09
Hemorrhage	15	-	1	6	4
Percentage (%)	57.69	-	3.84	23.07	15.38
Normal	5	-	7	5	5
Percentage (%)	21.73		30.43	21.73	21.73
Controls	18	-	1	8	3
Percentage (%)	60.00	-	3.33	26.66	10.00

3. Table showing anatomical variants seen in patients.

Carotid arteries	Patients
Normal	89
High riding bifurcation	2

Out of the total 89 patients examined by carotid Doppler 2 had bilateral high riding bifurcation. Examination of the internal and external carotids in high riding bifurcation is technically difficult.

4.Table showing the spectral velocity ranges in stenosed areas.

Percentage stenosis	Velocity ranges (m/s)	
	PSV	EDV
1-29	0.37-0.61	0.04-0.19
30-49	0.44-0.9	0.03-0.26
50-69	0.56-1.38	0.05-0.4
70-99	09-1.4	0.4-0.6
>99	Complete occlusion no flow	-

5.Table showing initima-media thickness in the study population on the affected side.

Sr. No.	IMT(in cm)	N	A	B	C	Control
1	0.07					
2	0.08	2				2
3	0.09	3				4
4	0.10	6	1	3	7	9
5	0.11	8	7	4	9	8
6	0.12	4	10	4	7	4
7	0.13		5	3	3	3
8	0.14		1	2		
9	0.15		1			
10	0.16		1			
	Total	23	26	16	26	30

Note – The affected side only studied. If fresh lesion on both sides then the carotid vessels studied on both sides.

6.Table showing incidence of Diabetes Mellitus (DM) and Hypertension (HTN) in Patients with carotid stenosis.

	Normal	1 - 29 %	30–49 %	50- 69 %	70- 99%	Near Occlusion	Total
Hypertension	9	9	3	5	1	1	28
Diabetes Mellitus	4	4	3	5	2	2	20

DISCUSSION

Stroke result from thrombo-embolism causing abrupt decrease in the cerebral perfusion with cerebral infarction or from intracerebral hemorrhage. The abrupt onset of focal neurologic deficit defines a stroke or CVA. It is a frequent indication of emergency neuroimaging.

The temporal classification includes TIA (Transient Ischemic Attacks), RIND (Reversible ischemic neurologic deficit), Progressing stroke (gradually progressing accumulative neurologic deficit involving over hours/days), and completed stroke (Severe or persistent stable neurologic deficit, as end stage of prolonged ischemia)[1]

Doppler enables us to know the status of the extra-cranial part of major vessels that are supplying the brain.

The purpose of this study was to demonstrate the impact of cerebral CT in patients who were initially diagnosed as having clinical symptoms and neurologic sings of Stroke / CVA and then to study the Carotid Doppler to correlate the various findings of Carotid Doppler with the CT findings.

Although majority of clinically diagnosed stroke patients have cerebrovascular diseases, episodes of rapid neurologic deficit may be caused by neoplasm , abscess or subdural haematoma.[2] In these patients , rapid clinical deterioration maybe caused by sudden shifts in intracranial pressure , mechanical pressure by the mass to cause venous infarction, peri-tumoral hemorrhage and sudden paroxysmal electrical activity. There is progressive neurological deterioration and presence of prodromal symptoms in patients with non-vascular i. e. non stroke lesions.

In our present study , out of 100 patients who presented clinically as CVA, 68 actually had stroke lesions ,where as 23 were normal and 9 had stroke mimics (i.e. 5 neoplasm, 1 subdural haematoma , 1 metastasis / primary , 1 Abscess / high grade neoplastic lesion , 1 AVM). The overall frequency of confirming CVA by CT in our study was 69 %.

The percentage of normal scans was 23 %, whereas 9 % were stroke mimics.

Out of the 91 patients, which were proved to have CVA on CT or were with normal CT findings but obvious neurological deficit (TIA / stroke in evolution), were divided into groups:

Group A – Patients with Large vessel infarct (26.37 %)

Group B – Patients with Small vessel / lacunar infarct. (17.58 %)

Group C - Patients with Primary non-traumatic Intracerebral / subarachnoid / Intraventricular Bleed (28.57 %)

Group N – CT findings were normal. These patients were interpreted as TIA or could be stroke in evolution (on basis of clinical findings of obvious neurological deficit) in acute stage where the CT could be normal. (25.27 %)

A few percentage 1.09 % had both small and large infarcts (A +B) which were considered in Group A for calculation purposes and few 2.19 % of cases had both infarction and hemorrhage (A+C), which were Hemorrhagic transformation of infarct and were considered as Group A for calculations . In our study, were infarctions more than hemorrhages, 43.95 % and 28.57 % respectively.

After excluding stroke mimics as SOL, infections (abscess), Subdural hemorrhage, and AVM, we carried out Carotid Doppler in a total of 91 patients who presented with cerbro-vascular symptoms. No cases of neck masses compressing the neck vessels was found , which could be labelled as a cause of reduced bood supply to the brain and cause symptoms of stroke were found.

The commonest lesion affecting the carotid arteries was atherosclerotic plaques. Of the 91 patients examined 37(40.65%) patients had no lesion, 54 (72%) patients had atherosclerotic plaques in the carotid arteries on the ipsilateral side of the CT lesion.

The patients with different CT findings as large infarcts, small infarcts, hemorrhage and normal were classified for the site of involvement in the extracranial carotid vessels, intima-media thickness (Table 2), nature of the plaque (echogenicity)(Table 3), degree od stenosis (Table 4) on the ipsilateral carotid vessel.The velocity ranges in the region of stenosis were also studies (Table 5)

The anatomical sites were classified as proximal and distal CCAs , carotid bulb, the ICA , ECA and VA according to the side involved. In the carotid arteries the commonest site of involvement was ICA (21 plaques) followed by carotid bulb (14 plaques).There were 8 lesions in the proximal CCA and 12 in the distal CCA. The ECA was least affected with 6 plaques (considering only the ipsilateral side of lesion on CT). More than one plaque was seen in a few patients, where the plaque with greater occlusion was considered for correlation with the nature of stroke on CT. Vertebral artery stenosis was not seen in any of the patients**.** Zwiebel WJ [3], found that the carotid bifurcation was commonly involved by the atherosclerotic plaque followed by the origin of the carotid arteries. In our study however commonest affected site was ICA followed by the carotid bifurcation. The origin of CCA was affected in only 1 case.

Kreb et al [4] also found that commonest site of involvement was carotid bifurcation followed by the cervical ICA and intracranial portion of ICA.

Gray-Weale et al,[5] classified palaques as type I to as follows: type I, predominantly echolucent plaque with a thin echogenic cap; type II, substantially echolucent lesions with small areas of echogenicity; type III, predominantly echogenic lesions with small areas of echolucency; and type IV, uniformly echogenic lesions (equivalent to homogeneous).

Plaques classified according to the echogenicity and was found that maximum plaques were of type II - 42.59 % (n= 23) & type III – 38.88% (n=21) of all plaques present. Type IV plaques were 18.51 % (n= 10) and none of the plaques were of type 1(Table 2).

Type of plaque (echogenicity) was correlated with the CT findings(Table 2).

In the 26 patients with large infarcts on CT, type 2 plaques were present in 65.38 % patients (n= 17) in the ipsilateral carotid artery. Type 2 plaques were significantly associated with large infarcts (p value < 0.01). Type 3 and type 4 plaques were present less commonly 26.92 % and 3.84 % in the ipsilateral carotid arteries. We know that type 2 plaques which are predominantly hypoechoic are more liable to dislodge as embolus and hence we could infer that the hypoechoic type 2 plaques could be responsible for large infarcts.

In 16 patients of lacunar infarcts on CT, type 3 plaques were present in 43.75 % patients (n= 7) in the carotid arteries ipsilateral to lesion on CT. Type 2 plaque (more than 50 % of plaque is hypoechoic) were present less commonly i.e 25 % in the ipsilateral carotids. Also it is known that type 3 plaques (more than 50% of plaque echogenic) are less liable to embolize and hence the cause of lacunar infarct could be somewhere more distally (small vessels) . Our findings were matching those of Tegos TJ et al (2001) [6] in which the large brain infarctions on CT was associated with hypoechoic plaques suggesting an involvement of extracranial carotid artery embolization, whereas the lacunar infarcts were associated with hyperechoic plaques suggesting an involvement of other mechanisms (hemodynamic, intracranial small and large vessel disease)

In the 26 patients of hemorrhagic stroke on CT 57.39 % ipsilateral carotids showed no plaque. Type 2, type 3 and type 4 plaques were present in 3.84, 23.07 and 15.38 % respectively. Thus ruling out any association of type 2 or type 3 plaques.

In the 23 normal patients on CT examination, carotid Doppler was done and the side on which lesion suspected clinically was taken into consideration for calculations. Of the 23 cases 30.43 % cases had type 2 plaques , & type 3 , type 4 plaques were present each 21.73% in carotid arteries on either side. Also 21.73 % patients had normal bilateral carotids. Thus even though the scans were normal the patients having plaques could be patients of TIA or acute stroke which may not be picked by CT in early.

According to Libby P [7] plaque characterization is very important as low echogenicity plaques are prone to ulceration and provide a nidus for formation of platelet thrombi. This may dislodge into the cerebral circulation and cause transient ischemic attacks. He also further stated that fibrous plaques permit coagulation factors in blood to form a thrombus that may occlude the blood vessel. Calcified plaques are resistant to rupture and unlikely to provoke thrombosis.

The patients were then classified according to the degree of stenosis that was present. This helps in evaluating treatment modalities in the patients (Table 1). Of the 91 patients 27 were normal i.e 29.67 % without any lumen occluding lesion ; 34 patients (37.36%) had 1 to 49 % stenosis or mild stenosis , and 26 patients had moderate stenosis i.e. 50-69 % and 4 patients (4.39 %) had 70-99% or critical stenosis.

We divided the degree of stenosis in to two groups, one > 50 % and other < 50 %. It was observer that out of 26 cases with large infarcts 69.23 % of the patients (n = 18) had >50 % stenosis in the carotid vessel ipsilateral to the lesion on CT. The association of > 50 % stenosis was found to be significant (p value < 0.01).We can thus infer that more severe degree of stenosis was associated with large infarcts.

In the 16 cases of lacunar infarcts 12.5% (n=2) had ipsilateral carotid stenosis more than 50%. 62.5 % of the patients (n= 10) had stenosis less than 50% and 25 % (n= 4) had normal carotids on the ipsilateral side of CT lesion. No association was found between lacunar infarcts and degree of stenosis in the ipsilateral carotid arteries.

In the 26 cases of haemorrhagic stroke only one (3.84 %) patient had ipsilateral carotid stenosis more than 50 % .Rest all had stenosis less than 50%, signifying that carotid stenosis was no way related to the hemorrhagic stroke and the single vessel with stenosis could be a chance finding.

Robinson ML et al [8] also classified patients according to the degree of stenosis. He classified them into 3 categories :-

1. Category 1-normal vessels with no stenosis.
2. Category 2-hemodynamically significant lesion, <70% stenosis no critical stenosis.
3. Category 3-critical stenosis >70%

The classification is necessary because stenosis <70% can be treated medically whereas patients with >70% stenosis need surgical treatment in the form of endarterectomy.

Grant et al [9], found that the mean PSV increases with increase in the degree of stenosis They found a specificity of 90.6% and also concluded that Doppler ultrasound is excellent method for the diagnosis of stenosis. In our study, we found that the PSV increased with increasing stenosis (Table 4). PSV measured in m/s was considered in ranges because of the variability in measurement. The velocity parameters to diagnose degree of stenosis matched the degree of stenosis by color flow method .

The anatomical variants seen in our study population included high riding bifurcation 2 patients (2.19 %). This was not clinically significant but there is difficulty in imaging the ICA and ECA (Table 3).

Diabetes mellitus, Hypertension were studied as risk factors for carotid stenosis . In our study out of the 20 patients that had diabetes only 4 (20 %) had normal carotid vessels and rest 16 (80 %) had stenosis ranging from minimal stenosis to near occlusion (Table 6). The association of diabetes mellitus with carotid stenosis was found to be significant and not by chance (p value < 0.01).The increased prevalence of diabetes and carotid atherosclerosis is thus proved.

Diabetes mellitus accelerates atherogenesis. Diabetes associated dyslipidemias strongly promote atherogenesis. If associated with insulin resistance and hypertension, it promotes plaque formation and hence atherogenesis. Singh AS et al [10] who in their study showed close association between glycated hemoglobin and carotid atherosclerosis in ischemic stroke.

Out of the 28 patients having hypertension n= 9 (32.14 %) had normal carotid vessels and rest n=19 (67.85 %) had stenosis ranging from minimal stenosis to near occlusion. The association of hypertension with carotid stenosis was found to be significant and not by chance (p value < 0.05).Hypertension is thus a risk factor for atherosclerosis. Ladecola et al.[11] have found that control of blood pressure leads to a substantially lower risk of stroke.

Intima-media (IM) thickness was considered separately. Mean IM thickness of the ipsilateral carotid arteries was calculated in all the groups of different types of stroke (Table 5). In our study mean IM thickness in controls was 0.10 cm, as compared to 0.12 cm in patients with large infarcts, 0.12 cm in patients with lacunar infarcts & 0.11 cm in patients with hemorrhagic stroke. Thus mean IM thickness was greater in the patients positive on CT. Mean IM thickness in symptomatic patients , but normal CT was 0.10 , which cannot be interpreted as the final out come of the these patients , weather they were TIA or hyper-acute stroke in evolution could not be confirmed on CT.

SUMMARY AND CONCLUSION

Color duplex ultrasound represents a significant advance in Doppler imaging technology. In addition to real time gray scale imaging it allows for color portrayal of the blood flow within the lumen of the vessel, along with the spectral waveforms. It is an accurate, rapid and reproductive means for detecting various lesions in carotid arteries.

The major advantages include (1)Ease of performance of the examination, (2)Non-invasiveness, (3) Easy availability, (4) Good technical efficiency and (5) Cost effectiveness.

When assessing the patients presenting with cerebrovascular symptoms. The commonest lesion we found was the atherosclerotic plaque (60 %). Early diagnosis and detection of the atherosclerotic plaque is important, as it is a predisposing condition for stroke. The various risk factors for atherosclerosis identified in our study include (1)Male sex, (2)DM, (3)HTN, (4)IHD

The prevalence of atherosclerotic plaque was 80% in diabetic subject and 68 % in hypertensive subjects. Occurrence of carotid plaque increases if the patient is a male.

Low echogenicity plaque, has a greater predictive value for development of stroke especially large vessel stroke. Severity of stenosis of the extra cranial carotid Doppler has significant association with large vessel infarcts and has no association with lacunar infarcts and Hemorrhagic stroke, the etiology of which could some thing different.

Thus every patient presenting with cerebrovascular symptom must undergo complete color duplex US examination of the carotid arteries, this will guide in selection of treatment modalities and will help in assessing the follow up of the disease and evaluating the effectiveness of treatment.

Figures and legend

Images 1. Longitudinal image showing hypoechoic plaque in the carotid bulb extending into the internal carotid artery causing mild to moderate luminal narrowing.

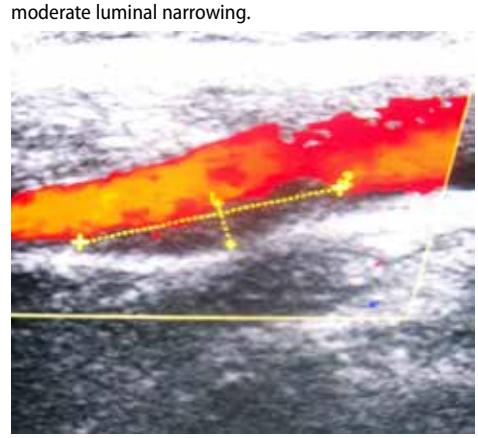


Image 2. Horizontal image of the Internal carotid artery showing a hypoechoic plaque causing 47 % luminal stenosis .

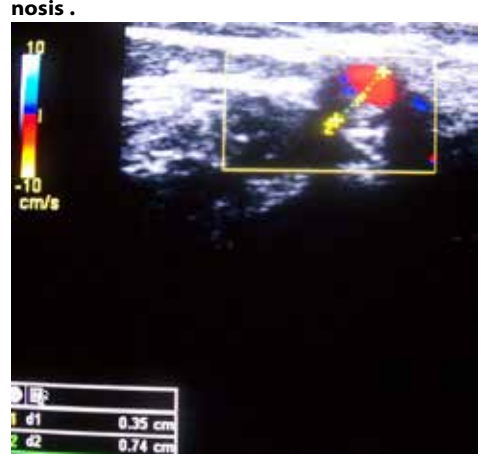


Image 3a, 3b, 3c. Pre-stenotic , Stenotic and post-stenotic velocities in the internal carotid artery.
Image 3a.

Image 3 b.

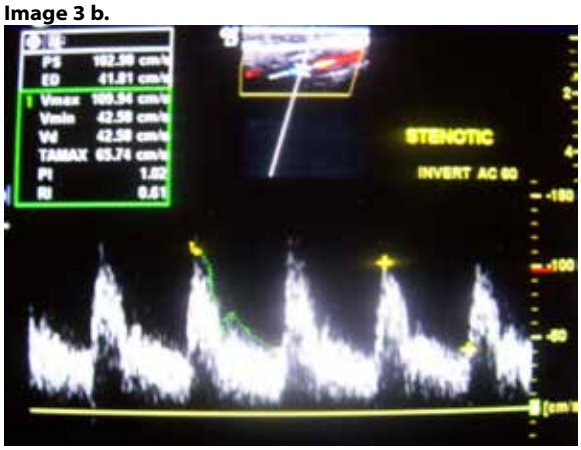
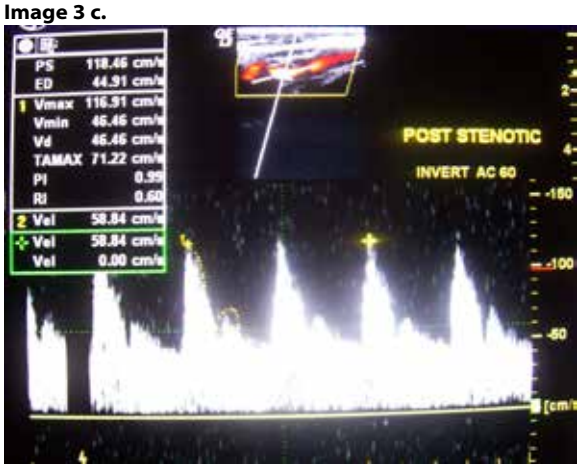


Image 3 c.



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