DOI: 10.36347/sjams.2017.v05i03.040

Scholars Journal of Applied Medical Sciences (SJAMS) **ISSN 2320-6691 (Online)**
Sch. J. App. Med. Sci., 2017; 5(3C):903-911 **ISSN 2347-954X (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com

Original Research Article

Study of Carotid Doppler findings and risk factors in patients presenting with Ischemic stroke

Dr Nadeem Ahmed[1], Dr Shaik Ismail[2], Dr Hima bindu Aerupula[3]
[1]Associate Professor, [2,3] Post graduate resident
Department of Radiodiagnosis, Kakatiya Medical College,Warangal.506007, Telangana

***Corresponding author**
Dr Nadeem Ahmed
Email: nadeem1975@rediffmail.com

Abstract: Atherosclerotic disease of carotid arteries outside the cranial cavity has been recognised as an important cause of ischemic stroke. Colour Doppler study of the carotid arteries is being used as a primary method to assess the carotid arteries. The objective of the present study was to study the frequency of changes in the carotid arteries by carotid doppler sonography and correlate them with findings of CT scan in cases presenting with ischemic stroke.The present study was done on 50 patients presenting with ischemic stroke. Presence of risk factors such as hypertension, diabetes, smoking and alcoholism was recorded. CT scan was done to record the presence, site and size of infarction. Colour Doppler analysis was done to calculate the intima- media thickness, presence and degree of carotid stenosis, presence, site and morphology of plaques and ratio of peak systolic velocity between internal and external carotid artery was recorded.The highest incidence of stroke was found in male population in the age group of 61-70 years. Among the risk factors maximum cases were of hypertension(48%) followed by alcoholism(32%) smoking(30%) and diabetes(26%) .Out of the 50 patients 12(24%) patients had significant stenosis of >50% and atherosclerotic plaques were seen in 38(76%) patients.Colour Doppler examination is an economic, safe , noninvasive method of demonstrating the presence and degree of atherosclerotic changes in the extra cranial carotid arteries causing ischemic brain infarction. This will guide use of proper treatment and surgical intervention in cases of severe stenosis.
Keywords: Colour Doppler ,CT scan, ischemic stroke, carotid stenosis, plaque

INTRODUCTION:

Stroke is the third leading cause of death worldwide after ischemic heart disease and cancer [1]. Early diagnosis is necessary to prevent mortality and morbidity. Moreover carotid endarterectomy or carotid stenting is the treatment of choice in cases of severe stenosis and can prevent stroke[2].Extracranial carotid stenosis can be easily and accurately measured using colour doppler imaging.

Stroke can be due to hemorrhage or ischaemia. Studies have shown that 80 to 85% strokes are caused due to cerebral infarction secondary to atherosclerosis of intracranial and extra cranial carotid vessels.[3,4]The most common source of emboli are from extra cranial carotid arteries with atherosclerotic disease. High degree internal carotid artery stenosis with plaque is the most important risk factor for the development of cerebrovascular disease along with other risk factors like diabetes hypertension, dyslipidemia and smoking[3]. Colour doppler study of carotid arteries combining high resolution imaging and doppler spectrum analysis is a safe ,easy ,noninvasive and cost effective method of evaluating the extracranial carotid arteries.[3] It can quantify the degree of stenosis caused by atherosclerosis in patients with stroke. Measurement of intima media thickness and plaque morphology may help in assessing the carotid artery as the source of the stroke.The sensitivity and specificity of carotid duplex ultrasound ranges from 90 to 95%.[5,6]

Computerised tomographic (CT) scan is the commonest investigation done in stroke to exclude hemorrhage and assess the presence or absence of infarction, its size site and nature. The aim of our study was to evaluate the frequency of carotid artery stenosis in ischemic stroke patients and to study the relationship

between the degree of carotid artery stenosis and presence and size of cerebral infarction on CT scan. Presence and type of plaque morphology was also noted.

MATERIAL AND METHODS:

A prospective observational study was conducted in the Department of Radiodiagnosis at Kakatiya Medical College and MGM Hospital, Warangal for a period of 7 months from August 2016 to February 2017. 50 patients presenting with stroke of all ages and both genders were included in the study. A detailed history and findings of clinical examination were noted in each case. Risk factors such as diabetes, hypertension, smoking and alcoholism were recorded. All patients underwent CT scan followed by colour doppler sonography of carotid and arteries. CT scan was done on 16 slice MDCT(GE) machine. Size and site of the infarct was noted .Colour doppler sonography was done on My Lab Classic C(Esaote) machine.Only cases presenting with ischemic stroke based on clinical history and CT findings were included in the study. Patients with head injury, neoplasms and haemorrhagic stroke were excluded from the study. The information noted from the CT scan included side of the infarct, vascular territory involved, and the time of CT scan after the onset of the symptoms. The infarcts were classified based on their size as small (<1.5cm) medium (1.5-3cm) and large (>3cm). The information noted from colour doppler included peak systolic velocity(PSV), intima media thickness, presence and type of plaque and diameter reduction of common carotid and internal carotid arteries (ICA)of both sides. ICA/CCA (common carotid artery) peak systolic velocity ratio was calculated. The data was analysed and presented in the form of tables and figures.

RESULTS:

A total of 50 patients of age ranging from 19-80 years with stroke underwent brain CT examination and colour doppler examination of their bilateral carotid arteries and findings were recorded. Among the 50 patients 26 patients(52%) were male and 24(48%) were female. Of the 50 patients studied 21 (42%) had right sided stroke and 29(58%) had left sided stroke. CT showed right sided infarct in 25 cases (50%) and left sided infarct in 22 cases (44%). 3 CT scans were normal. Bilateral involvement was not seen in any of our patients. Table 1 gives the age distribution of patients included in the study. Maximum number of patients were in the 60 to 70 years age (38%)group followed by 50 to 60 years(24%).There were 3 patients in the age groups less than 30 years.

Table 1: Age distribution of patients with stroke

Age group	Male	Female
<20 years	00	01
20-30 years	01	02
31-40 years	02	00
41-50 years	04	03
51-60 years	04	08
61-70 years	12	07
71-80 years	03	03
Total	26(52%)	24 (48%)

Among the risk factors studied ,maximum cases were of hypertension 29(48%) followed by alcoholism 16 cases(32%), smoking 15 cases(30%),and diabetes 13(26%) cases. Out of 12 cases showing more than 50% stenosis 6 had hypertension(50%), 4 had diabetes (33.33%),8 gave history of smoking(66.67%) and 9 were alcoholics(75%).

CT brain – non contrast CT of brain showed normal findings in 3 cases. In 2(4%) cases lacunar infarcts were seen . In 11(22%) cases infarct was small in size (<1.5cm), 16(32%) cases showed moderate size of the infarct(1.5-3cm) and 18(36%) cases showed a large infarct (> 3cm) on scanning. In 3(6%) cases CT findings were normal and multiple sites were involved in 7(14%) of the cases. Most common territory on either side was middle cerebral artery. Table-2 shows the location of infarct(arterial territory) found on CT scan.

Table 2: Location of infarct (arterial territory) on CT scan

Location of Infarct	Number
Right MCA infarct (middle cerebral artery)	17
Left MCA infarct	20
Right ACA (anterior carotid artery)	1
Left ACA	2
Right PCA (posterior cerebral artery)	2
Left PCA	3
Basilar	3
Right PICA (posterior inferior cerebellar artery)	4
Left PICA	1
Multiple involvement	7
Normal	3

Intima –media thickness- A significant intima-media thickness of more than 0.8mm was found in 44(68%) of the cases. Intima media thickness of >1mm was noted in 11(22%)cases.

Table 3: Shows intima media thickness in stroke patients

Intima Media Thickness	No of cases
<0.8mm	16(32%)
0.8-1mm	23(46%)
>1mm	11(22%)

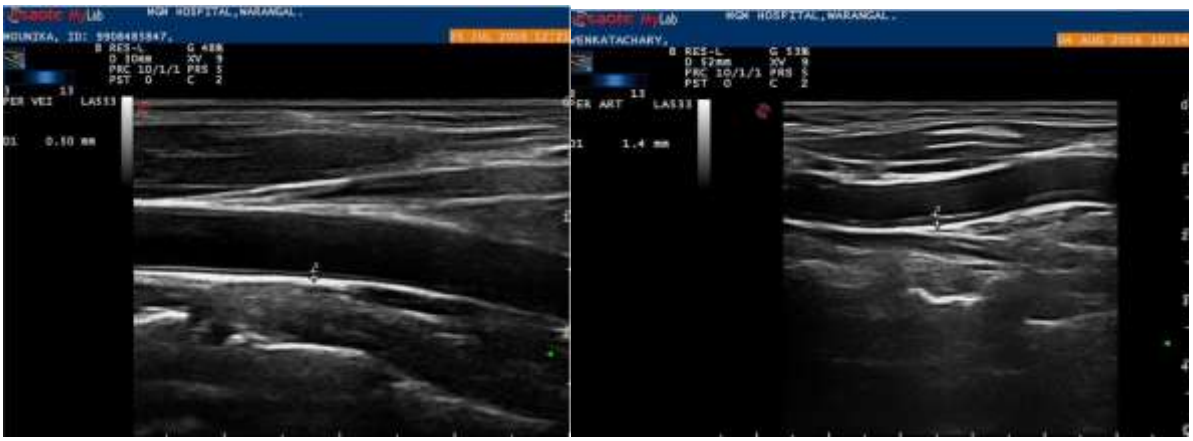
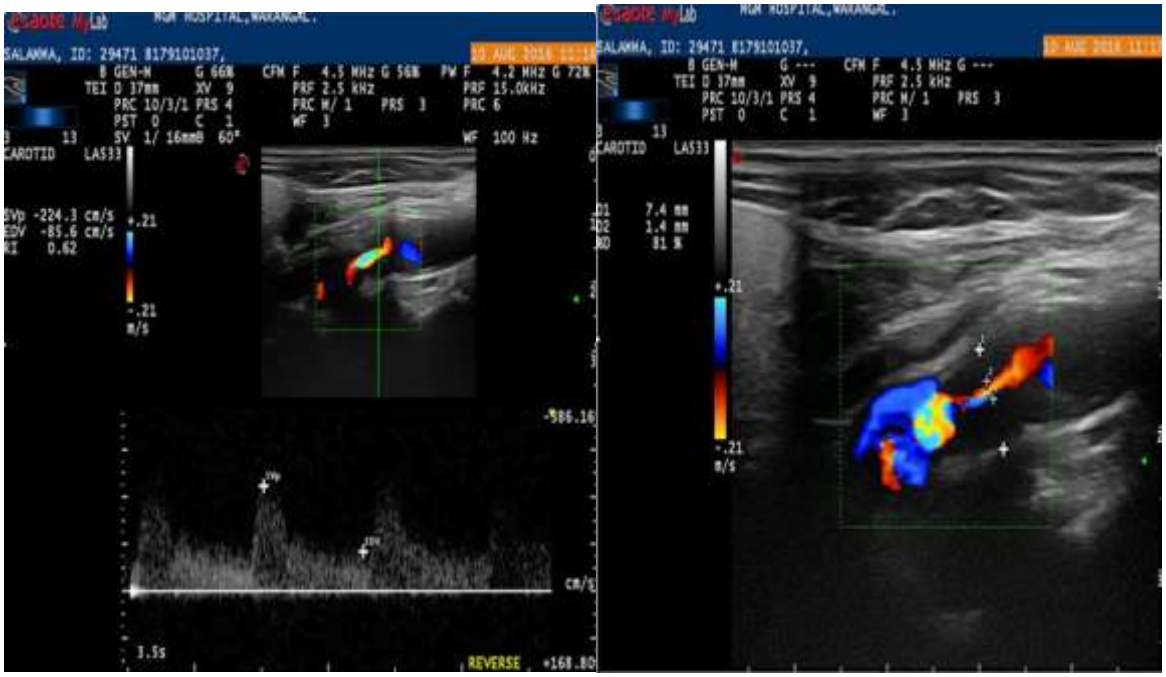


Fig 1 shows normal intima- media thickness versus increased intima-media thickness on the right side.

Degree of stenosis- Carotid doppler showed no stenosis in 16 (32%) patients. In 22(44%) cases diameter of the carotid arteries showed less than 50% stenosis. Significant stenosis of more than 50% was found in 9 patients(18%) and complete occlusion in 3(6%) patients.

Table 4 shows degree of carotid stenosis in stroke patients

Degree of stenosis	No of cases
No stenosis	16(32%)
Less than 50%	22(44%)
50-69%	7(14%)
70-99%	2(4%)
Complete occlusion	3(6%)



70

Fig 2: shows 81% luminal occlusion due to hypoechoic plaque with increased PSV (224cm/s) and PSV ratio of >1.8

Atheromatous plaques-Atherosclerotic changes in the form of atheromatous plaques were found to be the main cause of obstruction. Of the 38 patients having plaque in the extracranial carotid system (ICA and CCA) 31(62%) patients had bilateral involvement 3 (6%) had plaque on the right side and 4(8%) had plaque on the left side. The remaining 12 (24%) patients out of 50 showed no evidence of plaque. In our study combined involvement of both right and left carotid arteries as well as right and left internal carotid arteries was the commonest pattern seen in 20(40%) cases.

Table 5 shows the side and location of plaques in the internal or common carotid arteries.s

Location of Plaque	No of cases
RCCA only	3
LCCA only	1
RCCA+LCCA+RICA+LICA	20
LCCA+RCCA	5
LCCA+RCCA+LICA	3
LCCA+RCCA+RICA	1
LCCA+LICA	2
RCCA+RICA+LICA	2
LCCA+LICA	1
No plaque	12

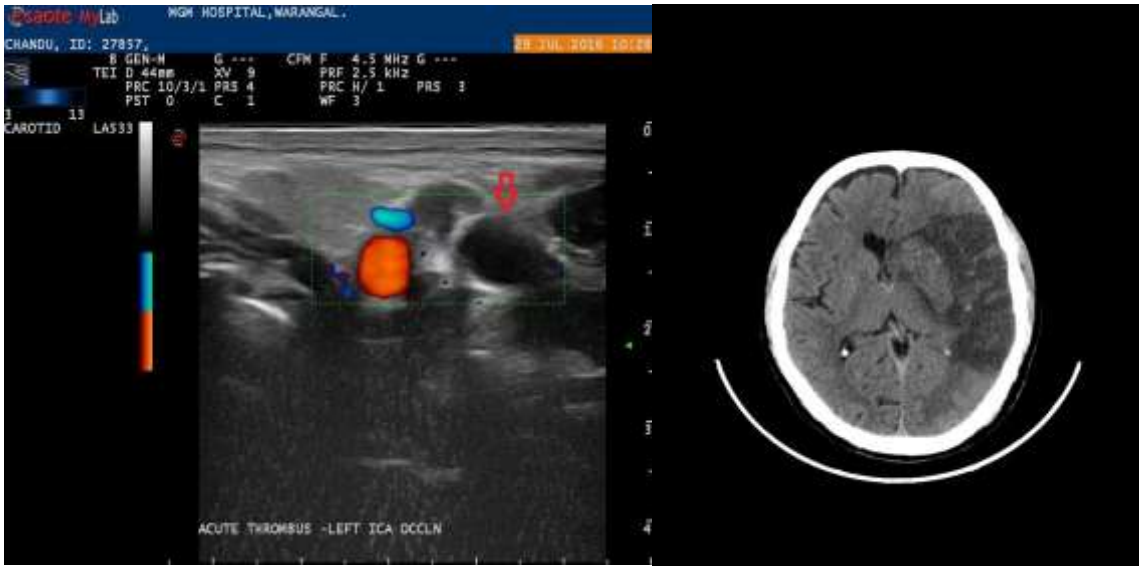


Fig 3: 40 yr old male with colour Doppler showing complete occlusion of left internal carotid artery and CT showing large infarct in left territory

Presence and type of plaque - On the right side, fibrofatty plaques were found in 25 cases while fibrocalcific plaques were found in 3 cases and hypoechoic plaques in 5 cases. On the left side, 23 cases showed fibro fatty plaque, 4 fibro calcific plaque and 5 cases had hypoechoic plaque. No plaques were noted in right carotid in 17(34%) cases and in the left carotid in 18(36%) cases.

Table 6: shows presence and type of plaque in stroke patients

Side	No Plaque	Hypoechoic plaque	Fibrofatty Plaque	Fibrocalcific Plaque
Right	17(34%)	5(10%)	25(50%)	3(6%)
Left	18(36%)	5(10%)	23(46%)	4(8%)

Ratio of peak systolic velocities in ICA and CCA -Using the criteria of ICA/CCA ratio there were 8 pts with > 1.5 ratio,3 with >1.8 ratio and one showing complete occlusion on the right side .Out of the 10 patients with significant occlusion on the left side there were 4 patients with ratio of >1.5, 2 with >1.8, 1 with > 3.7, 1 with near total occlusion and 1 with complete occlusion.

Table 7: shows PSV ICA/CCA ratio in the right and left carotid arteries(n=100)

	<1.5	>=1.5	>=1.8	>=3.7	OCCLUSION NEAR TOTAL	OCCLUSION TOTAL
RT	38	8	3	0	0	1
LT	40	4	2	1	1	2

Fig 4: Normal measurement of PSV and EDV in internal carotid artery

DISCUSSION:

Atherosclerotic disease affecting the extracranial carotid arteries (usually within 2cms of the carotid bifurcation) is responsible for 30-60% of the strokes [7]. Doppler sonography is the primary nonivasive test to evaluate carotid stenosis. It also detects the presence of plaque and its characteristics which helps in the selection of patients for endarterectomy [8]. The present study was done to correlate the findings of carotid Doppler with CT scan in patients presenting with ischemic stroke. Bowman *et al.;* reported that the incidence of stroke increases after the age of 60 years[9]. In our study maximum number of patients were in the age group of 61 to 70 years (38%) followed by 51 to 60 years.(24%). Fernandes *et al.;* have reported maximum cases in the 60 to 69 years (32%) which is similar to our study while 26% of their cases were in 70 to 79 years which was unlike our study [3]. Ahmed *et al.;* reported maximum cases in 50 to 59 years(33.87%)[10]. There was a slight male preponderance (52%)as compared to the females in our study. Most other studies have shown stroke to be much more prevalent in males with 72% reported by Fernandes *et al.;* and 97.5% by Iemolo *et al.;* [3, 8]. This difference in age group and gender could be because of differences in risk factors like diabetes and hypertension in the population and age and duration of smoking.

Hypertension, diabetes mellitus and smoking are known risk factors for stroke. In our study of the 50 patients 29(48%) were hypertensive out of which 6 presented with severe stenosis (>50%). Lawes *et al.;* in a large study of 188000 hypertension patients found stroke in 6800 cases[11]. Fernandes et al have reported hypertension in 38 % of their cases with severe stenosis in 4 cases[3].Smoking increases the risk of stroke. It was estimated in a study by Mannami *et al.;* that 22% of stroke cases were attributed to smoking.[12] There was a history of smoking in 15 (30%) cases of which 8 presented with severe stenosis. Fernandes *et al.;* have found 40% of their patients with history of smoking with 30% having significant stenosis [3]. This shows that smoking is associated with severe stenosis. Diabetes is another important risk factor for development of stroke. In the present study 13(26%) patients had diabetes out of which 4 had severe stenosis. In a study reported by Lindsberg and Roine diabetes mellitus was found in two thirds of patients of ischemic stroke [13]. Fernandes *et al.;* have reported an incidence of 16% diabetes mellitus in their cases of stroke of which 37% had significant stenosis [3]. Ahmed *et al.;* have reported smoking and hypertension to be more frequent in patients with higher degree of stenosis in their study [10].

The parameters studied on carotid doppler to study stenosis are PSV, EDV, or PSV ratio, IMT, narrowing of the lumen and presence and type of plaque. Intima media thickness(IMT)is considered an important marker for atherosclerotic disease not only in cerebrovascular system but for the whole arterial system [14]. It is believed that thickening of IMT complex greater than 0.8mm is abnormal and may represent the earliest change of atherosclerotic disease [2,14]. In our study IMT was <0.8 in 16 cases(32%), 0.8-1mm in 23 cases (46%) and >1mm in 11(22%) cases. Mean IMT was 1.7mm in stroke patients and 1.1mm in patients

with transient ischemic attack (TIA) in a study by Bhagwat *et al.;* [15] Malik *et al.;* have found mean IMT to be 1.1mm in stroke patients.[14] Ahmed *et al.;* found increased IMT in 58.1% of their cases while it was 68% in our study[10]. Similar results were reported by Toubul *et al.;* and Bots *et al.;* who reported that there was a significantly higher incidence of stroke in patients with who had increased IMT suggesting a relation between brain infarction related to atherosclerosis irrespective to the presence of stenosis. [16,17]. Hence carotid IMT has emerged as an independent marker of atherosclerosis and cerebrovascular disease. Increased IMT is associated with risk factors of stroke [18]. Rajeev *et al.;* have done a study on CIMT in patients with ischemic stroke and its correlation with risk factors [18]. He concluded that patients with risk factors like diabetes mellitus , dyslipedemia and smoking have higher CIMT. These patients should undergo screening with colour doppler for early medical or surgical intervention and lifestyle management.

The detection of carotid stenosis and occlusion with colour duplex sonography relies mainly on the combination of B mode and colour encoded flow imaging [2]. The severity of the carotid stenosis may be evaluated by measuring the diameter or area of residual lumen and diameter or area of original lumen. The percentage of luminal reduction can be calculated [2]. In our study 16 (32%) cases had no stenosis and carotid stenosis was found in 42(84%) cases. Majority cases showed stenosis of <50% in 22 cases. In 7 cases it was 50-69%, in 2 cases it was 70-99 % and complete occlusion was found in 3 cases. Hence 22 cases (44%) had less than 50% stenosis ,while 12 cases (24%) had more than 50% that is significant stenosis. Hadi *et al.;* in a similar study have reported 56% cases of stroke with stenosis with 35.6% having significant stenosis of > 50% while Razzak *et al.;* have reported it to be 31% [19,20]. Razaq *et al.;* and Atif *et al.;* have both reported significant stenosis in 21% of their cases which is similar to our study.[20,21] Wasay *et al.;* in a study of 672 patients reported significant stenosis in 21% cases [22]. Even in asymptomatic patients significant stenosis of 17% and 14% has been reported by Alexandrove and Ahn *et al.;* [23, 24] .This calls for the screening of high risk cases. Bhagat *et al.;* have found 70 % patients with > 50%stenosis having a large infarct while only 25% with <50% stenosis had a large infarct[15] .In our study 75% patients with > 50% had large infarct while 65.7% patients with <50% stenosis had a large infarct. Malik *et al.;* have also reported a higher incidence of larger infarct in patients with > 50% stenosis with only 25% patients with <50% having larger infarcts [14].

Carotid plaques are believed to be a marker of generalized atherosclerosis and a potential source of thromboembolism .Carotid plaque composition, localization and degree of stenosis are important predictive factors of cerebrovascular events. Many authors have suggested that low echogenicity in plaque demonstrates a high correlation with intraplaque hemorrhage and these have strong association with cerebrovascular events. Atherosclerotic changes in the form of atheromatous plaques were found in 38 (70%) patients out of which 31(62%) had bilateral involvement. Plaques of fibrofatty type were found in 24(48%%)cases fibrocalcific plaques were found in 10(20%) patients and hypoechoic plaques in 4(8%). Multiple plaques involving both the right and left common carotid and internal carotid artery were found in 40% of our cases. Ozlem *et al.;* reported presence of plaque in 51.3% of the cases[1]. In other studies Hadi *et al.;* reported soft plaques in 58.9% while Razzak *et al.;* in 43% of their cases[19,20]. Malik *et al.;* reported plaques in 84% cases presenting with ischemic stroke which is higher than our study[16]. Multiplicity of plaques was thrice in stroke patients compared to TIA patients in their study. Najim et al reported 63% cases with plaques while Sahoo et al reported plaques in 30% cases [25, 26]. Bhagwat *et al.;* have found ICA to be the common site of plaques in 43.7% cases out of which 46% had a smooth and 46.7% an irregular configuration.[15] Fernandes *et al.;* found plaques in 39(78%) of cases with 23 having bilateral involvement [3]. ICA was the commonest site with 9 cases [3]. Soft plaques, heterogenous and low echogenic plaques show more positive correlation with symptoms than with any degree of stenosis and were the cause of adverse neurological symptoms. The risk of embolization or rapid progression would depend on plaque composition especially if it was heterogenous, diffuse or focal. It has been reported that composition of plaques in symptomatic patients is significantly different from those of asymptomatic patients, the former containing more total lipid and cholesterol and less collagen and calcium[15]. Hemorrhage and ulceration of plaque plays an important role in cerebrovascular disease.

Peak systolic velocity(PSV)ratio has been considered one of the best parameter for assessing stenosis except in cases of complete occlusion. The systolic ratio is derived by dividing the PSV at the stenotic zone of the ICA by PSV obtained at normal portion of CCA [2]. A ratio of >1.5 indicates 50% or greater stenosis, a ratio of >1.8 is an indicator of 60% or greater stenosis and >3.8 or more than 80% diameter

stenosis [2]. Using the criteria of ICA/CCA ratio there were 8 pts with > 1.5 ratio, 3 with >1.8 ratio and one showing complete occlusion .Out of the 10 patients with significant occlusion on the left side there were 4 patients with ratio of >1.5, 2 with >1.8, 1 with > 3.7, 1 with near total occlusion and 1 with complete occlusion. Fernandes *et al.;* found the ratio to be >1.8 in 10 patients out of which 3 had a ratio of >3.7. In 3 of their patients with complete occlusion as there was no flow this could not be assessed [3]. Features of complete occlusion are absence of arterial pulsation, lumen filled with echogenic material ,subnormal vessel size and absence of Doppler flow signals or weak Doppler signals [3].We found complete occlusion in 1 case on right and 2 on left side while Fernandes *et al.;* have reported 1 case each of complete occlusion on right and left side [3].

CONCLUSION:

The present study has shown that atherosclerosis of the extracranial carotid arteries is associated with ischemic stroke. Carotid doppler is a very useful technique in detecting the site and morphology of atherosclerotic plaques and quantifying the degree of stenosis. Hence it should be used as a primary line of investigation in patients presenting with ischemic stroke as well as to screen the high risk patients. This will help in determining the proper treatment protocol. Patients with mild to moderate stenosis will require lifestyle modification and control of risk factors. In patients with more than 70% stenosis surgical intervention like endarterectomy can be more beneficial than medical treatment.

REFERENCES:

1. Kalayci TO, Sonmezgoz F, Apaydin M, Inci MF, Erdogan H, Oyar O, Çakir H, Kestelli M. Effects of carotid artery stenosis and plaque localization on the incidence of cerebral infarct and diameter of vertebral artery: a duplex ultrasonography and MRI evaluation. International Journal of Clinical & Experimental Medicine. 2016 Nov 1;9(11).
2. Rajagopal KV, Lakhkar BN, Banavali S, Singh NK. Pictorial essay: Color duplex evaluation of carotid occlusive lesions. Indian Journal of Radiology and Imaging. 2000 Oct 1;10(4):221.
3. 3.Fernandes M, Keerthiraj B, Mahale AR, Kumar A, Dudekela A. Evaluation of Carotid Arteries in Stroke patients using Color Doppler sonography: A prospective study conducted in a tertiary care hospital in South India. Int J Appl Basic Med Res. 2016 Jan-Mar; 6(1): 38–44.
4. Konin B, Konin SB, Saraf N, Kinhal S, MR S. Correlation Of Neurologic Dysfunction With Ct-Scan Brain Findings And Carotid Doppler Study In Acute Ischemic Stroke. 2014;3(68): 14574-14587.
5. Brown PB, Zwiebel WJ, Call GK. Degree of cervical carotid artery stenosis and hemispheric stroke: duplex US findings. Radiology. 1989 Feb;170(2):541-3.
6. Jahromi AS, Cinà CS, Liu Y, Clase CM. Sensitivity and specificity of color duplex ultrasound measurement in the estimation of internal carotid artery stenosis: a systematic review and meta-analysis. Journal of vascular surgery. 2005 Jun 30;41(6):962-72.
7. Bluth EI, McVay LV, Merritt CR, Sullivan MA. The identification of ulcerative plaque with high resolution duplex carotid scanning. Journal of ultrasound in medicine. 1988 Feb 1;7(2):73-6.
8. Iemolo F, Martiniuk A, Steinman DA, Spence JD. Sex differences in carotid plaque and stenosis. Stroke. 2004 Feb 1;35(2):477-81.
9. Bowman TS, Sesso HD, Ma J, Kurth T, Kase CS, Stampfer MJ, Gaziano JM. Cholesterol and the risk of ischemic stroke. Stroke. 2003 Dec 1;34(12):2930-4.
10. Ahmed L, Noori A. Carotid Doppler Study in patients with Cerebral Infarction. J Fac Med Baghdad. 2011; 53 (4): 363-66.
11. Lawes CM, Bennett DA, Feigin VL, Rodgers A. Blood pressure and stroke. Stroke. 2004 Mar 1;35(3):776-85.
12. Mannami T, Iso H, Baba S, Sasaki S, Okada K, Konishi M, Tsugane S. Cigarette smoking and risk of stroke and its subtypes among middle-aged Japanese men and women. Stroke. 2004 Jun 1;35(6):1248-53.
13. Lindsberg PJ, Roine RO. Hyperglycemia in acute stroke. Stroke. 2004;35:363–4.
14. Rajesh M, Tiwari R. Carotid Doppler Evaluation of Transient Ischemic Attack and Stroke Patients and its correlation with the CT scan head: A prospective study. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS). 2013;7:20-5.
15. Bhagat H, Goyani BR, Ukani BV, Vadel MK, Sheth R. The Role of Colour Doppler And Spectral Flow Analysis In Pregnancy Induced Hypertension: A Case Control Study. National Journal of Medical Research. 2015;5(1):57-60.
16. Touboul PJ, Elbaz A, Koller C, Lucas C, Adraï V, Chédru F, Amarenco P, GÉNIC Investigators. Common carotid artery intima-media thickness and brain infarction. Circulation. 2000 Jul 18;102(3):313-8.
17. Bots ML, Hoes AW, Koudstaal PJ, Hofman A, Grobbee DE. Common carotid intima-media

thickness and risk of stroke and myocardial infarction. Circulation. 1997 Sep 2;96(5):1432-7.
18. Rajeev H, Krishnappa , Savitha V. Study of intima-media thickness in patients with acute ischemic stroke and its correlation with risk factors of ischemic stroke-A case control study .Journal of Evolution of Medical and Dental Sciences .2013; 2: 44 (4) 8444-8454.
19. ul Hadi N, Khan R, Awan KH, Iqba N. Frequency of Carotid Artery Stenosis in Ischemic Stroke by using Carotid Doppler Ultrasonography in a Teaching Hospital. Gomal Journal of Medical Sciences. 2009 Dec 31;7(2).
20. Razzaq AA, Khan BA, Jadoon CK, Baig SM. Carotid Doppler ultrasonography in young stroke patients. JPMA. The Journal of the Pakistan Medical Association. 1999 Apr;49(4):97-9.
21. Atif MA, Ali H, Mahmood T. Frequency of carotid atherosclerosis in cerebral infarction. Pakistan journal of medical sciences. 2008 Jan 1;24(1):69.
22. Wasay M, Azeemuddin M, Masroor I, Sajjad Z, Ahmed R, Khealani BA, Malik MA, Afridi MB, Kamal A. Frequency and outcome of carotid atheromatous disease in patients with stroke in Pakistan. Stroke. 2009 Mar 1;40(3):708-12.
23. Alexandrova NA, Gibson WC, Maggisano R. Carotid artery disease and peripheral vascular disease. Stroke. 1995;26:175.
24. Ahn SS, Baker JD, Walden K, Moore WS. Which asymptomatic patients should undergo routine screening carotid duplex scan? The American journal of surgery. 1991 Aug 1;162(2):180-4.
25. Najim M M. Carotid Doppler In Stroke Patient, Stroke, 2007; 38: 1655.
26. Sahoo R, Krishna MV, Subrahmaniyan DK, Dutta TK, Elangovan S. Common carotid intima-media thickness in acute ischemic stroke: A case control study. Neurology India. 2009 Sep 1;57(5):627.