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Evaluation of the carotid arteries using grayscale and color Doppler ultrasonography in stroke patients

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ABSTRACT

Introduction: Stroke causes neurological dysfunction by cerebral or spinal infarction. Ultrasound of the carotid arteries is beneficial for the management of carotid atherosclerosis. Multiple risk factors exist for the occurrence of large artery stroke.

Methodology: This prospective descriptive study was conducted in a tertiary Care Centre from March 2023 to March 2024. Ethical clearance was taken from the Institutional Review Committee (Ref no: 816/2023). Purposive sampling was used to include 204 patients with stroke/transient ischemic attacks. Variables collected were demographics, evaluation of comorbidities, previous medical history, family history, and carotid ultrasound including grayscale and color Doppler.

Results: The mean age of the patients was 68.39 ± 9.35 years with a male predominance. Carotid plaques were seen in 91.67%. The most common artery was the left common carotid and the most common type of plaque was the heterogeneous type. Severe narrowing of the arteries was seen in 20.09% with complete occlusion in 8.33% and 8.82% of cases in the right and left internal carotid arteries respectively. Increasing age, hypertension, diabetes, dyslipidemia, smoking, and family history were important risk factors for the occurrence of stroke. A carotid intima-medial thickness of over 1 mm was observed in 40.68% and 35.76% of the right and left common carotid arteries, respectively.

Conclusion: Carotid gray scale ultrasonography revealed significant carotid plaque status in patients of stroke. The presence of comorbidities increases the risk of stroke and carotid plaque. Color Doppler ultrasound of carotids is a useful tool for managing carotid atherosclerosis.

INTRODUCTION

Stroke is defined as an episode of neurological dysfunction caused by focal cerebral, spinal, or retinal infarction.[1] Transient Ischemic Attacks (TIA) are brief episodes of neurological dysfunction due to cerebral ischemia without permanent cerebral infarction. The 24-hour threshold for TIA and stroke is less useful nowadays.[22]Stroke is mostly ischemic in about 85% of cases while hemorrhagic in the rest. Ischemic events are mostly caused by atherosclerosis of intracranial and extracranial carotid vessels.[3, 4] Ultrasound imaging of the carotid arteries is the method of choice for triage, diagnosis, and monitoring of carotid atherosclerosis.[5] Risk factors for large artery stroke are increasing carotid stenosis, hypertension, diabetes, or a combination.[6]

The proper screening and evaluation of carotid arteries in stroke patients is still lacking in resource-lacking areas such as ours. Evaluation of carotid arteries in high-risk patients of stroke is of great importance in the management of such patients to reduce morbidity and mortality.

METHODOLOGY

This was a descriptive, cross-sectional study done by collecting data from 22nd March 2023 to 20th March 2024. In this research, patients referred to the radiology department for evaluation of extracranial carotid arteries using ultrasonography were studied. Ethical approval was taken from the Institutional Review Committee (Ref: 816/2023). This study aims to study the characteristics of the carotid arteries, like various plaques morphology as well as the degree of carotid artery stenosis based on cross-sectional area measurement in patients with stroke/TIA, along with the comorbidities present in such patients. Data was collected after obtaining written informed consent from the patients included in the study, following a thorough explanation of the nature and purpose of the study. All patients referred to the radiology department to evaluate extracranial carotid arteries using ultrasonography were included in the study. Uncooperative patients and those unwilling to give consent were excluded from the study.

Variables like age, sex, smoking history, medical history of diabetes, hypertension, dyslipidemia, history of stroke/TIA, family history of stroke, common carotid arteries plaque, internal carotid arteries plaque, their luminal narrowing, intima-medial thickness (IMT) at the middle of common carotid arteries were studied during the study. A purposive sampling technique was used for data collection.

In a study done by Park et. al., in 500 patients with risk factors, the overall presence of carotid stenosis was 7.4 %.[7]

The sample size was calculated using the following formula:

$N = (Z^2 \times p \times q)/e^2$

$= (1.96^2 \times 0.074 \times 0.926)/0.05^2$

~ 105

At a prevalence of 7.4%, a 5% margin of error, and a 95% confidence interval, the sample size was calculated to be 105 cases. To increase the study's accuracy, 204 cases that fulfilled inclusion criteria were included. The patient was first examined by a physician, including detailed history, physical examination, including vitals, clinically stroke is diagnosed and subsequently referred to our department. In our department, I evaluated the patients, including demographics and brief history; thereafter the USG scan was done using grayscale and color Doppler using the GE Voluson S10 using high-frequency linear probe 9L-RS, 4-10 megahertz. Patients were kept in supine position with their necks slightly extended. Firstly thyroid gland was identified in the mid-neck region, and then, turning the probe by 90 degrees, the CCA was identified, and it was followed cranially to visualize the ICA and CCA. The plaque character was graded as hypoechoic, echogenic, heterogeneous, or calcified. The luminal narrowing was categorized into mild (<50% narrowing), moderate (50-69% narrowing), severe (≥70% narrowing), or complete occlusion. IMT was measured at the middle common carotid arteries level. Hypertension was considered positive if systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg, or with the use of anti-hypertensive for earlier diagnosed hypertension.[8] Diabetes mellitus was considered as per ADA criteria, or the use of oral hypoglycaemic or insulin.[9] Dyslipidemia was diagnosed as per JAC guidelines or the use of statins or fibrates[10]. Positive smoking history was taken as current smokers or smokers having smoked at least 100 cigarettes in their lifetime.[7]

The data were entered in a Microsoft Excel sheet and statistical analysis was done with IBM SPSS Statistics for Windows, version 29 (IBM Corp., Armonk, N.Y., USA).

Results

Over the study period of a year, 204 cases of patients with stroke or TIA were evaluated for carotid artery status using grayscale and color Ultrasound Doppler. The cases were sampled using the purposive sampling method, for a required minimum sample size of 105; however, 204 cases were evaluated to strengthen the study's accuracy.

The mean age of the patients was 68.39 ± 9.35 years. The majority of them were male (154, 75.49%), with a male/female ratio of 3.08. Among the patients, 31 (15.2%) patients had a previous history of stroke/TIA. Demographics and past history are tabulated in Table 1.

Table 1: Demographic and Medical History of the Patients (n=204)

Variables	N	Percentage
Age		
Mean	68.39 ± 9.35 years	
Minimum	44 years	
Maximum	90 years	
Sex		
Male	154	75.49%
Female	50	24.51%
History of previous stroke/TIA		
Yes	31	15.2%
No	173	84.8%
Family history of stroke		
Yes	52	25.49%
No	152	74.51%
Significant Smoking History		
Yes	129	63.24%
No	75	36.76%
Hypertension		
Yes	115	56.37%
No	89	43.63%
Diabetes		
Yes	63	30.88%
No	141	69.12%
Dyslipidemia		
Yes	43	21.08%
No	161	78.92%

On Ultrasound Doppler, the plaque status of both sides' common carotid and internal carotid arteries was evaluated. Among 204 patients, 187 (91.67%) had positive plaque status. The most common vessel with plaque was left common carotid with 159 (77.94%) cases. Heterogeneous plaque was the most common finding in the left common carotid, present in 80 (39.22%) cases. The findings of plaque status are tabulated in Table 2.

Table 2: Plaque characteristics (n=204)

Plaque Status	N	Percentage
Presence of plaque		
Yes	187	91.67%
No	17	8.33%
Right Common Carotid		
No plaque	84	41.18%
Echogenic	26	12.74%
Hypoechoic	44	21.57%
Heterogeneous	26	12.74%
Calcified	24	11.77%
Right Internal Carotid		
No plaque	62	30.39%
Echogenic	50	24.51%
Hypoechoic	37	18.14%
Heterogeneous	27	13.24%
Calcified	28	13.72%
Left Common Carotid		
No plaque	45	22.06%
Echogenic	13	6.37%
Hypoechoic	38	18.63%
Heterogeneous	80	39.22%
Calcified	28	13.72%
Left Internal Carotid		
No plaque	87	42.65%
Echogenic	19	9.31%
Hypoechoic	67	32.84%
Heterogeneous	4	1.96%
Calcified	27	13.24%

All patients were also evaluated for luminal narrowing and IMT. Most patients showed no narrowing while mild narrowing was the second-most common. Complete obstruction of the right internal carotid was seen in 17 (8.33%) while in 18 (8.82%) cases of the left internal carotid. The findings are tabulated in Table 3.

Table 3: Carotid narrowing and IMT. (n=204)

Variables	N	Percentage
Right Common Carotid Narrowing		
No narrowing	98	48.04%
Mild (<50%)	92	45.1%
Moderate (50-69%)	14	6.86%
Severe (≥70%)	0	0%
Complete occlusion	0	0%
Right Internal Carotid Narrowing		
No narrowing	74	36.28%
Mild (<50%)	52	25.49%
Moderate (50-69%)	33	16.18%
Severe (≥70%)	28	13.72%
Complete occlusion	17	8.33%
Left Common Carotid Narrowing		
No narrowing	100	49.02%
Mild (<50%)	97	47.55%
Moderate (50-69%)	4	1.96%
Severe (≥70%)	3	1.47%
Complete occlusion	0	0%
Left Internal Carotid Narrowing		
No narrowing	60	29.41%
Mild (<50%)	81	39.71%
Moderate (50-69%)	35	17.16%
Severe (≥70%)	10	4.9%
Complete occlusion	18	8.82%
Right Intima-Medial Thickness		
Mean	1.0 ± 0.3	
0.6 mm	mm	10.29%
0.7 mm	21	9.31%
1.8 mm	19	7.35%
1.9 mm	15	11.77%
1 mm	24	20.59%
1.1 mm	42	5.88%
1.2 mm	12	8.82%
1.3 mm	18	6.38%
1.4 mm	13	10.78%
1.5 mm	22	3.43%
1.6 mm	7	2.45%
1.8 mm	5	2.95%
	6	
Left Intima-Medial Thickness		
Mean	1.0 ± 0.3	
0.6 mm	mm	3.43%
0.7 mm	7	27.45%
0.8 mm	56	1.96%
0.9 mm	4	18.14%
1 mm	37	12.25%
1.1 mm	25	7.84%
1.2 mm	16	8.33%
1.3 mm	17	5.4%
1.4 mm	11	3.92%
1.5 mm	8	1.96%
1.6 mm	4	4.42%
1.8 mm	9	4.9%
	10	

DISCUSSION

Atherosclerosis of the internal carotid arteries within 2 cm of the carotid bifurcation contributes to around 60% of strokes.[6] The American Society of Echocardiography recommends ultrasound to assess carotid arteries, characterize atherosclerosis, and evaluate the cardiovascular risk associated with it.[11] In the study, we assessed the status of carotid arteries in patients with stroke/TIA.

During our study, we observed 204 patients with stroke/TIA. Among the patients, a majority, 154 (75.49%), were males. A meta-analysis done by Paudel et. al., including 55 studies of stroke in Nepal, revealed that in Nepal, the risk of stroke is higher in men than in women.[12] A study done by Fernandes et. al., found stroke incidence to be higher in males (72%) than females (28%).[6] Similarly, a systematic review done by Appelros et. al., including 98 studies of stroke, concluded that the incidence of stroke is 33% higher in males than in females.[13] This is similar to our findings.

In our study, the mean age of the patients was 68.39 ± 9.35 years, with a minimum of 44 years and a maximum of 90 years. We saw an increased incidence of stroke with increasing age. We saw the greatest incidence of stroke in the age group between 60 and 75 years. This peak of stroke with age was also evidenced by Paudel et. al., who found the average age of stroke in Nepal to be 62.4 years, which is similar to our findings.[12] Similarly, in India, the average age of stroke is 62.2 years.[14] In a comparative study by Rahbar et. al., the average age of stroke in low-income countries was only 63.1 years while the mean age in high-income countries was 68.6 years. Stroke care and prevention are directly

proportional to income, which directly relates to the mean age of stroke.[15]

We observed that 115 (56.37%) stroke patients had hypertension. According to the review, published in the European Cardiology Review, done by Wajngarten and Silva, hypertension is the most prevalent risk factor for stroke, present in around 64% of patients with stroke. This is similar to the findings of our study.[16] In our study, 63 (30.88%) stroke patients had diabetes. In a study published in the Journal of Stroke, it was found that the overall prevalence of diabetes among stroke patients is 28%, with an increased prevalence in ischemic stroke patients at 33%.[17]

Smoking has a great impact on stroke and plaque outcomes. A meta-analysis done by Pan et. al., observed that smokers have an odds ratio (OR) of 1.61 compared to non-smokers.[18] During our study, the majority of the patients were smokers as well, which likely increased the stroke incidence. Schulz et al. in their research found that a family history of stroke is present in around 23% of patients with stroke.[19] In this study, 52 (25.49%) patients had a family history of stroke. According to a population-based cohort study, the risk of recurrence of stroke is around 12%.[20] We observed that 31(15.2%) of the patients in our study, had a recurrent attack of stroke/TIA. In the study conducted by Manish Raj Pathak, 58% of patients were male, which is similar to our study where 75% of patients are male. In the same study hypertension and smoking were the most prevalent risk factor which is similar to our study. In the same study, calcified plaque was most common type, whereas in our study it was heterogeneous plaque was more common.[28]

In our study, 187 (91.67%) patients had significant plaque in either of their common or internal carotid arteries. Fernandez in their research found 78% of the patients to have a significant plaque in their carotids.[6] Gyawali, in their research, however found only 43.3% of patients with ischemic stroke to have a significant plaque in their carotids.[4] Schulte-Altedorneburg in their study found the presence of plaque in about 64% of patients with stroke/TIA.[21] The most common site of carotid plaque is the carotid bulb.[22] In our study, the most common site was the left common carotid artery in 159 (77.94%) of the cases. The most common type of plaque was the heterogenous type in 80 (39.22%) of the cases of left common carotid plaques, followed by the hypoechogenic type in 38 (18.63%) cases. According to Tegos et al. hypoechoic plaques are more prone to cerebrovascular accidents.[23] Calcified plaque was the least common plaque observed in the examination of the carotids during our evaluation.

In our study, we observed that 41 (20.09%) of the stroke patients had severe occlusion (≥70%), while complete obstruction of the right internal carotid was seen in 17 (8.33%) and in 18 (8.82%) cases of the left internal carotid. Stenosis of more than 50% increases the likelihood of stroke/TIA. Significant stenosis is consistent with persistent neurological symptoms.[6, 24] Carotid endarterectomy is beneficial in cases of moderate and severe occlusion.[25] Carotid intima-medial thickness increases according to age. It is generally less than 0.7 mm in women and 0.8 mm in men.[26] Increased IMT is an indicator of atherosclerosis and increased risk of cerebrovascular accident.[27] The carotid IMT of > 1mm is generally taken as increased IMT. In our study, we found that there were 83 (40.68%) cases of increased IMT in the right common carotid while there were 75 (36.76%) cases of increased IMT in the left common carotid artery.

CONCLUSION

Grayscale and color Doppler ultrasound revealed that 91.67% of the patients with stroke/TIA had significant plaques in their common or internal carotid arteries. Severe narrowing was seen in 20.09% of patients, while complete occlusion was seen in 8.82%. Increasing age, diabetes, hypertension, smoking, family history, and dyslipidemia were associated with increased risk of atherosclerosis. Carotid Doppler is a noninvasive and easy method for stratifying the risk of atherosclerosis in carotid arteries and is necessary for the management of high-risk patients who have cerebrovascular accidents.

LIMITATION OF THE STUDY

Our study had several limitations. It was a single-center study, done in only 204 cases of stroke which is a poor predictor for the general population. The ultrasound of carotids is still liable to inter-observer biases. Further studies with spectral Doppler indices like PSV and its ratio of ICA/CCA will make the study more accurate. Another limitation that is paramount to mention is that stroke was not diagnosed with imaging modalities like CT/MRI, which would have made our study more legitimate.

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CONFLICT OF INTEREST: None

FINANCIAL DISCLOSURE: None

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