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USEFULNESS OF CAROTID DOPPLER ULTRASOUND FOR DETECTION OF SIGNIFICANT CAROTID ARTERY STENOSIS IN PATIENTS WITH ISCHEMIC STROKE

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ABSTRACT

Background: *A main risk factor for ischemic stroke is carotid artery stenosis; hence, early identification with non-invasive imaging modalities such carotid Doppler ultrasonic waves is essential to prevent stroke recurrence and guide therapy options.* **Objectives:** *To investigate its correlation with demographic and clinical risk variables as well as assess the efficacy of carotid Doppler ultrasonic in identifying notable carotid artery stenosis in patients of ischemic stroke.* **Methods:** *We included 221 ischemic stroke patients in this cross-sectional study at Pak Emirates Military Hospital, Rawalpindi, from July 2024 to October 2024. The degree of stenosis in the left and right carotid arteries was measured using carotid Doppler ultrasounds. The right and left arteries were compared in terms of hemodynamic characteristics including end-diastolic velocity (EDV) and peak systolic velocity (PSV).* **Results:** *Among 221 patients, 41.6% had either severe (≥70%) or intermediate (50–69%) stenosis. Male gender (p=0.038), older age (p=0.001), hypertension (p=0.013), diabetes (p=0.029), hyperlipidemia (p=0.008) and smoking (p=0.042) all substantially correlated severe stenosis. While EDV was much higher in the right artery (p=0.043), peak systolic velocity did not change appreciably between the right and left arteries (p=0.089). Compared to patients with moderate stenosis, those with severe stenosis had more incidence of ischemic stroke.* **Conclusion:***In stroke patients, carotid doppler ultrasounds are useful instruments for early identification and evaluation of notable carotid artery stenosis. Emphasizing the need of effective management of hypertension, diabetes, and hyperlipidemia to lower the risk of recurrent ischemic episodes and improve clinical outcomes, the study finds strongly linked modifiable risk variables highly connected with severe stenosis.*

Keywords: *Carotid artery stenosis, Ischemic stroke, Doppler ultrasound, Risk factors, Hemodynamics, Stroke prevention*

INTRODUCTION

A main cause of ischemic stroke is carotid artery stenosis, the disorder marked by the carotid arteries' narrowing. The main cause of this vascular disease is atherosclerosis, in which case plaque accumulation reduces blood supply to the brain, raising stroke and transient ischemic attack (TIAs) risk [1]. Implementing appropriate treatments to stop recurrence of ischemia episodes depends on early identification and accurate assessment of carotid artery stenosis. Carotid Doppler ultrasonic scans are among the most often used non-invasive diagnostic tools for carotid stenosis evaluation [2]. Its ability to

precisely identify and measure the degree of stenosis makes it the necessary instrument in the treatment of stroke victims [3].

Using high-frequency sound waves, carotid Doppler ultrasonic images the structure and flow dynamics of carotid arteries, therefore offering real-time data on blood flow velocity, turbulence and plaque features [4-5].Among the benefits this imaging method provides are non-invasive character, cost-effectiveness, safety and general availability. Carotid Doppler is appropriate for routine screening, especially in high-risk groups, since it does not expose patients to ionizing radiation or contrast chemicals unlike more intrusive operations like digital subtraction angiography (DSA) [6]. Furthermore, operation is somewhat short, painless and repeatable, which helps doctors track illness development and assess therapy effectiveness [3].

Carotid Doppler ultrasonic waves have applications outside only stenosis detection. It is absolutely important for stratifying risk, separating symptomatic from asymptomatic individuals and directing treatment options [7-8]. Patients with severe carotid stenosis (usually >70% narrowing) found by Doppler imaging, for example, would benefit from procedures including stenting or carotid endarterectomy (CEA), which have been demonstrated to greatly lower the risk of recurrent stroke [9]. Moreover, Doppler ultrasonic results can help to identify susceptible plaques, which are linked to the higher risk of embolic events, hence guiding the requirement of aggressive medical treatment [10-11].

For the diagnosis and treatment of significant carotid artery stenosis in patients with ischemic stroke, carotid Doppler ultrasounds are, all things considered, being useful, non-invasive imaging tool. Its diagnostic accuracy, safety and value in treatment decision-making make it an essential part of whole assessment of stroke patients. The study intended to assess the value of carotid Doppler ultrasonic waves in influencing clinical decision-making for stroke prevention and therapy as well as in spotting significant carotid artery stenosis in patients with ischemic stroke.

Materials and Methods

From July 2024 until October 2024, this cross-sectional study took place at Pak Emirates Military Hospital in Rawalpindi, on ischemic stroke patients. The study comprised 220 male and female patients who were presented with acute ischemic stroke verified by neuroimaging (CT or MRI) during the course of research. Patients were drawn from the outpatient neurology clinic and inpatient stroke unit. Adults 40 years of age or older with recent history of ischemic stroke or TIA were included; these were characterized as either the sudden onset of neurological impairments lasting more than 24 hours or resolving within 24 hours, respectively. Patients excluded were those with prior carotid endarterectomy, carotid stenting, non-atherosclerotic causes of carotid artery stenosis (e.g., dissection, fibromuscular dysplasia).

The estimated prevalence of substantial carotid artery stenosis in stroke patients and reasonable margin of error helped to ascertain a total sample size of 220 patients. Starting with qualified patients consecutively, convenience sampling was employed to enroll the necessary sample size.

Using a standardized proforma, thorough clinical data, including demographic, medical history (e.g., hypertension, diabetes, hyperlipidemia and smoking status), as well as stroke characteristics was gathered at enrollment. Utilizing the high-resolution Doppler machine, e.g., GE Logic E9 or equivalent, all patients received carotid Doppler ultrasounds under the direction of qualified radiologists utilizing 7–12 MHz linear transducer. The patients were reclined, head slightly extended and turned contralateral to the side under observation. Bilateral imaging of the common carotid artery, carotid bifurcation, internal and external carotid arteries was done according to standard procedure.

We analyzed Doppler ultrasonic images to evaluate the degree of stenosis depending on peak systolic velocity (PSV), end-diastolic velocity (EDV) and ratio of internal carotid artery PSV to common carotid artery PSV. The Society of Radiologists in Ultrasound (SRU) guidelines defined the degree of stenosis as follows: 50% (mild), 50–69% (moderate) and ≥70% (severe). Furthermore recorded were plaque form and existence of echogenic or calcified plaques.

Data were entered and examined using SPSS version 26. While categorical factors like sex and stenosis degree were provided as frequencies and percentages, continuous variables including age and Doppler velocity measurements were presented as mean ± standard deviation (SD). Chi-square tests for categorical data and independent t-tests for continuous variables allowed us to assess the

relationship between clinical factors and notable carotid artery stenosis (≥70% narrowing). Considered statistically significant was the p-value of under 0.05.

Written informed consent was obtained from every participant and Institutional Review Board of Pak Emirates Military Hospital, approved the project. Throughout this trial, patient data was kept under confidentially; standard clinical treatment included ultrasonic examinations, so there was no extra danger to patients.

Results

The demographic and clinical traits of the study population showed that most of the participants were men (58.8%). With respect to the occurrence of carotid artery stenosis, sexes showed statistically significant differences (p=0.024). Age distribution showed that biggest proportion of patients fell in 50-59 age bracket (33.0%), followed by 60-69 years (27.6%) and statistically significant relationship between age and stenosis severity (p=0.005). With all demonstrating significant correlations with carotid artery disease (p=0.008, p=0.032, and p=0.011, respectively), hypertension was the most common comorbidity among the clinical variables (62.9%), followed by diabetes mellitus (43.4%) and hyperlipidemia (33.5%). While the history of coronary artery disease and past TIAs were less common, with only previous TIAs indicating significant link, smoking was present in 41.6% of the patients and was also substantially associated (p=0.046) (Table 1).

Doppler ultrasonic testing was used to evaluate the degree of carotid artery stenosis; results were separated for the right and left carotid arteries. Of individuals with the right carotid artery, 43.4% had mild stenosis (<50%), 23.5% had moderate stenosis (50–69%), 10.9% had severe stenosis (≥70%) and 22.2% had no discernible stenosis. With the p=0.001 these variances were statistically significant. In the left carotid artery, similarly, mild stenosis was present in 39.4%, moderate stenosis in 27.6% and severe stenosis in 13.1% of patients; 19.9% had no stenosis (p=0.003). With a strong correlation between bilateral stenosis degree and patient characteristics (p=0.015), bilateral stenosis analysis found that 18.6% had mild, 15.4% had moderate and 8.6% had severe stenosis. This implied that sizable fraction of patients had major bilateral illness (Table 2).

Patients with severe stenosis were notably older (mean age: 67.4 years vs. 58.2 years, p<0.001), according to a correlation between major carotid stenosis (≥70%) and clinical characteristics. With the p=0.038, men were more likely than women to suffer severe stenosis. Patients with severe stenosis (p=0.013) had notably greater hypertension; diabetes mellitus (p=0.029), smoking (p=0.042) and hyperlipidemia (p=0.008) were also rather common in these patients. With comparable numbers of patients in the severe stenosis group (37) compared to the mild stenosis group (37), hyperlipidemia notably showed the strongest connection despite the latter group being almost three times larger. These results underlined the important influence of modifiable risk factors in the development of severe stenosis, therefore stressing the need of aggressive risk factor control in this population (Table 3).

Three facets of carotid artery stenosis were emphasized. A higher risk of embolization was indicated by the predominance of heterogeneous plaques in both right and left carotid arteries; stroke type distribution shows ischemic strokes are more frequent than TIAs, especially in patients with ≥70% stenosis; risk factor analysis reveals hypertension, diabetes, hyperlipidemia and smoking was significantly associated with severe stenosis, so stressing the need of managing these factors to prevent disease progression and stroke events (Figure 1). The comparison of velocity parameters between the right and left carotid arteries showed no significant difference in peak systolic velocity (PSV) (p=0.089). However, end-diastolic velocity (EDV) was significantly higher in the right carotid artery compared to the left (p=0.043), suggesting possible variations in hemodynamic flow patterns between the two arteries (Table 4).

Table 1: Demographic and Clinical Characteristics of Study Population (n = 221)

Variable	Frequency (n)	Percentage (%)	p-value
Gender			
Male	130	58.8	0.024*
Female	91	41.2	
Age Group (Years)			0.005*
40-49	37	16.7	
50-59	73	33.0	
60-69	61	27.6	
70 and above	50	22.6	
Medical History			
Hypertension	139	62.9	0.008*
Diabetes Mellitus	96	43.4	0.032*
Hyperlipidemia	74	33.5	0.011*
Smoking	92	41.6	0.046*
History of Coronary Artery Disease	49	22.2	0.071
Previous TIA	31	14.0	0.028*

*Significant at $p<0.05$

Table 2: Severity of Carotid Artery Stenosis Based on Doppler Ultrasound Findings (n = 221)

Stenosis Severity	Frequency (n)	Percentage (%)	p-value
Right Carotid Artery			
<50% (Mild)	96	43.4	0.001*
50-69% (Moderate)	52	23.5	
≥70% (Severe)	24	10.9	
No Stenosis	49	22.2	
Left Carotid Artery			
<50% (Mild)	87	39.4	0.003*
50-69% (Moderate)	61	27.6	
≥70% (Severe)	29	13.1	
No Stenosis	44	19.9	
Bilateral Stenosis			
Mild	41	18.6	0.015*
Moderate	34	15.4	
Severe	19	8.6	

*Significant at $p<0.05$

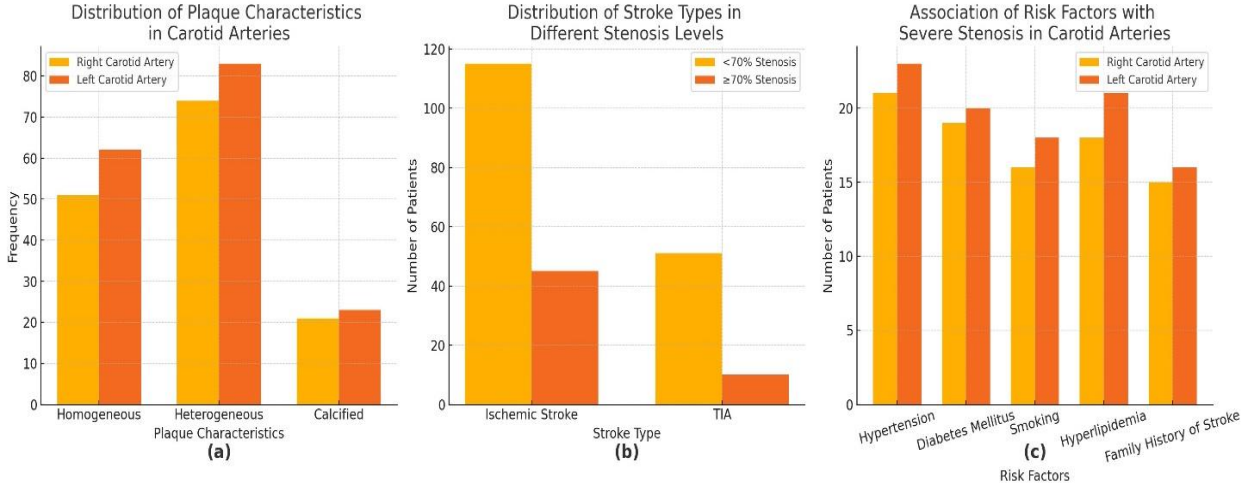
Table 3: Association Between Significant Carotid Stenosis (≥70%) and Clinical Variables (n = 221)

Variable	Stenosis <70% (n = 166)	Stenosis ≥70% (n = 55)	Chi-Square (χ^2)	p-value
Age (mean ± SD)	58.2 ± 10.4	67.4 ± 9.2	14.201	<0.001*
Gender			4.317	0.038*
Male	85	45		
Female	81	10		
Hypertension			6.730	0.013*
Yes	96	43		
No	70	12		
Diabetes Mellitus			4.523	0.029*

Yes	61	35		
No	105	20		
Smoking			4.135	0.042*
Yes	63	29		
No	103	26		
Hyperlipidemia			9.754	0.008*
Yes	37	37		
No	129	18		

*Significant at p<0.05

Figure 1: Comparative Analysis of Plaque Characteristics, Stroke Types, and Risk Factor Associations in Patients with Carotid Artery Stenosis.



(a) Distribution of Plaque Characteristics in Carotid Arteries.
(b) Distribution of Stroke Types in Different Stenosis Levels.
(c) Association of Risk Factors with Severe Stenosis in Carotid Arteries.

Table 4: Comparison of Peak Systolic Velocity (PSV) and End-Diastolic Velocity (EDV) in Right and Left Carotid Arteries (n = 221)

Velocity Parameter (cm/s)	Right Carotid (Mean ± SD)	Left Carotid (Mean ± SD)	t-value	p-value
Peak Systolic Velocity (PSV)	180.5 ± 35.2	175.8 ± 38.7	1.712	0.089
End-Diastolic Velocity (EDV)	50.8 ± 15.4	47.2 ± 17.0	2.045	0.043*

*Significant at p<0.05

Discussion

In patients with ischemic stroke, this study assessed the value of carotid Doppler ultrasonic waves in identifying notable carotid artery stenosis and investigated their correlation with other clinical factors. The results showed that Doppler ultrasonic waves clearly distinguished several degrees of stenosis in the carotid arteries, therefore proving their important function as a non-invasive diagnostic tool for stroke risk assessment. Since patients with severe stenosis (≥70%) are at increased risk of future strokes and TIAs, early identification and quantification of carotid artery stenosis are absolutely crucial in preventing repeated ischemic events [1, 12]. The findings are consistent with earlier research stressing that carotid Doppler ultrasonic imaging is a dependable method with great sensitivity and

specificity for assessing the degree of stenosis and tracking disease development [13].

Severe carotid stenosis was found to be much correlated with male gender, advanced age, advanced degree and existence of cardiovascular comorbidities according to the demographic study. This is consistent with current research pointing out these risk factors as main drivers of atherosclerotic disease's development [14]. Especially those with hyperlipidemia exhibited a particularly strong correlation with severe stenosis, which emphasized the importance of rigorous lipid-lowering treatment in this high-risk category. Observed in our investigation, prevalence of male patients with severe stenosis also reflected the results of other studies, implying a possible gender-specific sensitivity to carotid atherosclerosis [7, 15].

Peak systolic velocity (PSV) and end-diastolic velocity (EDV) among the hemodynamic parameters assessed offered more understanding of the flow dynamics in stenotic carotid arteries. Although PSV did not change much between the right and left carotid arteries, the higher EDV in the right artery may point to uneven hemodynamic flow patterns, which would affect plaque stability and embolization risk [16-17]. These results highlighted the need of thorough hemodynamic examination in order to identify minor variations that can influence clinical therapy when assessing carotid stenosis.

With patients reporting more frequency of ischemic stroke than those with mild or moderate stenosis, the study also showed strong link between severe stenosis and clinical outcomes. This is consistent with earlier studies finding poor prognosis and significant carotid stenosis as a predictor of stroke recurrence [18-20]. These findings confirm the use of carotid Doppler ultrasonic waves not only for diagnosis but also for guiding therapeutic decisions, such deciding whether patients with symptomatic severe stenosis require carotid endarterectomy or stenting.

Conclusion

Providing vital information on plaque shape and hemodynamic flow, carotid Doppler ultrasounds shown to be a consistent, non-invasive method for identifying and characterizing different degrees of carotid artery stenosis in ischemic stroke patients. Emphasizing the effect of these risk factors on disease progression, the study found strong correlations between severe stenosis (≥70%) and important clinical variables including age, male gender, hypertension, diabetes mellitus, hyperlipidemia, and smoking. Right carotid artery elevated end-diastolic velocities point to uneven flow dynamics possibly affecting plaque stability. Particularly in directing interventional techniques like carotid endarterectomy or stenting for patients with high-grade stenosis, these results support the integration of carotid Doppler ultrasonic imaging into regular stroke evaluations for appropriate risk stratification and management.

Conflict of Interest

None.

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