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Validity of Carotid Doppler Ultrasound in Diagnosing Carotid Artery Stenosis among Ischemic Stroke Patients: A Prospective Study with Computed Tomography as the Gold Standard

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Abstract: Background A common non-invasive imaging technique used in clinical practice to assess carotid artery disease is carotid Doppler ultrasound. However, a thorough assessment is required to determine its diagnostic accuracy in detecting carotid artery stenosis in individuals who have had ischemic strokes in comparison to the gold standard CT angiography. Although carotid Doppler ultrasonography has benefits like real-time imaging and no ionizing radiation, its precision might vary based on patient characteristics, operator skill, and technological constraints. **Study design:** Cross-sectional (validation) study.**Settings**: Department of Radiology, Fauji Foundation Hospital Rawalpindi.**Duration of study:** 20 May 2025 to 20 August 2025.**Methodology:** Total 152 patients between the ages of 30 and 70 years who had an ischemic stroke were included. Patients who had previously had stroke treatment or who had hemorrhagic stroke were not included. Each patient had duplex ultrasonography utilizing a Toshiba Apalio equipped with a linear transducer probe operating at L 3–12 MHz. The measurement of the intimal medial thickness (IMT) of the common carotid artery (CCA) and other extracranial arteries. Once stenosis was detected, the velocities were assessed at the point of maximum stenosis. All patients underwent CT angiography. **Results:** According to our study, carotid doppler ultrasonography's sensitivity, specificity, PPV, NPV, and diagnostic accuracy for identifying carotid artery stenosis in ischemic stroke patients were 87.65%, 81.69%, 84.52%, 85.29%, and 84.87%, respectively, using computed tomography as the gold standard.**Conclusion:** The usefulness of Carotid Doppler Ultrasound as a non-invasive, reasonably priced, and trustworthy screening method for identifying carotid artery stenosis in ischemic stroke patients is highlighted in this study.

Keywords: Carotid artery, Doppler ultrasonography, Ischemic stroke, sensitivity, stenosis.

INTRODUCTION

Stroke is the leading cause of disability and the most prevalent neurological condition that can be fatal.1 Depending on the region that the blocked vascular system supplies, ischemic stroke is defined by thrombotic or ischemic blockage of any vessel, resulting in loss of function accompanied by symptoms.2 According to population-based studies, large artery atherosclerotic disease accounts for 15–46% of ischemic strokes, making it a significant cause

of stroke.3 The primary cause of big artery stroke is extracranial internal carotid artery stenosis (CAS).3 One of the most used diagnostic tests in neurological inpatient and outpatient departments is extracranial neurovascular ultrasonography of the carotid arteries, which is a cutting-edge examination for all patients with ischemic stroke.4 A considerable percentage of stroke patients have carotid artery disease as their underlying cause. All patients with ischemic strokes or transient ischemic episodes who are candidates for carotid intervention should be referred for carotid imaging as soon as possible, ideally within 24 hours, according to the most recent acute stroke care recommendations.5 However, the local frequency of CAS determines whether these suggestions are applicable in certain groups.3 Among ischemic stroke patients, the frequency of carotid atherosclerosis was 23.9% in a research carried out in Burkina Faso.6 A color doppler is easy to get and can be used instead of a CT scan by someone who knows how to use it. One study indicated the overall sensitivity (89.5%), specificity (76.20%), PPV (45.50%), NPV (93.88%), and diagnostic accuracy (76.90%) of Doppler Ultrasound.7

With computed tomography as the gold standard, the purpose of this study is to ascertain the diagnostic accuracy of carotid doppler ultrasound for the identification of carotid artery stenosis in patients who have had ischemic stroke. When making clinical management decisions, such as starting medication therapy, deciding whether surgery (such as a carotid endarterectomy) is necessary, or estimating the likelihood of a stroke recurrence, accurate detection of carotid artery stenosis is crucial. A common non-invasive imaging technique used in clinical practice to assess carotid artery disease is carotid Doppler ultrasound. However, a thorough assessment is required to determine its diagnostic accuracy in detecting carotid artery stenosis in individuals who have had ischemic strokes in comparison to the gold standard CT angiography. Although carotid Doppler ultrasonography has benefits like real-time imaging and no ionizing radiation, its precision might vary based on patient characteristics, operator skill, and technological constraints. Patients will benefit from this study's non-invasive diagnostic technique, which will aid in early and precise diagnosis and subsequent treatment.

METHODOLOGY:

This study was conducted at Department of Radiology, Fauji Foundation Hospital Rawalpindi from 20 May 2025 to 20 August 2025. Total 152 patients between the ages of 30 and 70 who presented to the Radiology Department of Fauji Foundation Hospital Rawalpindi and who had an ischemic stroke (defined as weakness of any half or limb of the body, i.e., power less than 5/5 of both upper limb and lower limb of that half) and a confirmatory CT scan demonstrating acute cerebral ischemia (hypodense area) were the subjects of this descriptive, cross-sectional validation study. With a 95% confidence level, 23.9% carotid artery stenosis frequency in ischemic stroke patients[6], 89.5% sensitivity (10% absolute precision), and 76.2% specificity (10% absolute precision), the sample size was determined using a sensitivity and specificity calculator.[7] There will be 152 patients in the sample. Patients were selected using a non-random consecutive sampling technique. Patients who had previously had stroke treatment or who had hemorrhagic stroke were not included.

The institutional ethical review board approved the conduct of this research. After informing the guardians of the study's goals, advantages, and risks, their written informed consent was obtained. Age, gender, and the length of symptoms were among the demographic details recorded. A thorough medical history has been obtained, and a physical examination will be conducted. Each patient had duplex ultrasonography utilizing a Toshiba Apalio equipped with a linear transducer probe operating at L 3–12 MHz. Taking measurements of the intimal medial thickness (IMT) of the common carotid artery (CCA) and other arteries outside the brain. For each patient, the IMT at the distal wall of the CCA was measured on both sides, and the higher of the two values was used. We employed the L 3–12 MHz linear transducer probe to find the peak systolic and end diastolic velocities in the common, internal, and external carotid arteries (CCA, ICA, and ECA). When stenosis was found, the speeds were checked at the place where it was most severe. All patients underwent CT angiography. A proforma was made just for entering data.

SPSS version 25.0 was used to enter and evaluate data. For quantitative data such as age and symptom duration, the mean and standard deviation were computed. For categorical factors such as gender and patients with carotid artery stenosis diagnosed by color doppler and CT scan, frequency and percentage were computed. Using a CT scan as the gold standard, diagnostic accuracy, sen, spec, PPV, and NPV were computed for color doppler findings using a 2x2 table. Data stratification was used to account for effect modifiers such as age, gender, and illness duration in order to improve diagnostic accuracy. By creating a 2x2 table, the post-stratification diagnostic accuracy was determined.

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Diagnosis of carotid artery stenosis by color doppler	**Diagnosis of carotid artery stenosis by CT scan**	
	Yes	**No**
Yes	TP	FP
No	FN	TN

RESULTS:
With a mean age of 58.77 ± 10.02 years, the study's participants ranged in age from 30 to 70. Table I shows that 96 patients, or 63.16% of the total, were between the ages of 51 and 70. With a male to female ratio of 1.5:1, 92 (60.53%) of these 152 patients were men and 60 (39.47%) were women. The average duration of the symptoms was 4.97 ± 2.15 days. The distribution of patients with various factors is shown in Table I.
13 patients (False Positive) had no carotid artery stenosis on their CT scan, but 71 patients (True Positive) who had carotid artery stenosis on their doppler USG also had carotid artery stenosis on their CT scan. Table II shows that 10 of the 68 patients who did not have carotid artery stenosis on doppler USG did have it on CT scan (False Negative), while 58 of the patients who did not have it on CT scan (True Negative) did not have it on CT scan (p=0.0001). Using CT as the gold standard, our study found that carotid doppler ultrasonography was 87.65% sensitive, 81.69% specific, 84.52% positive predictive, 85.29% negative predictive, and 84.87% accurate for diagnosing carotid artery stenosis in patients with ischemic stroke. The diagnosis accuracy stratification by age, gender, and symptom duration is shown in Table III.

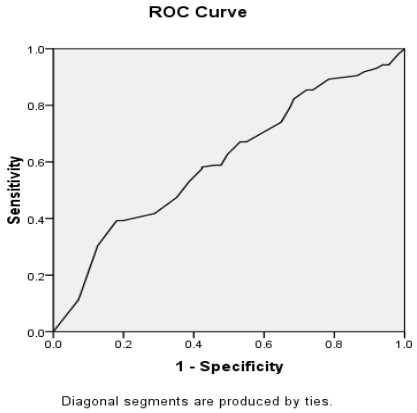
Table I: Distribution of patients with confounding variables (n=152)

Confounding variables		**Frequency**	**%age**
Age (years)	30-50	56	36.84
	51-70	96	63.16
Gender	Male	92	60.53
	Female	60	39.47
Duration of symptoms (days)	≤7	101	66.45
	>7	51	33.55

Table-II: The diagnostic accuracy of carotid Doppler ultrasound for identifying carotid artery stenosis in ischemic stroke patients, using computed tomography as the gold standard..

	Carotid artery stenosis on CT scan	**No Carotid artery stenosis on CT scan**	**P-value**
Carotid artery stenosis on doppler USG	71 (True positive)	13 (False Positive)	0.0001
No Carotid artery stenosis on doppler USG	10 (False negative)	58 (True Negative)	

Sensitivity: 87.65%
Specificity: 81.69%
Positive Predictive Value (PPV): 84.52%
Negative Predictive Value (NPV): 85.29%
Diagnostic Accuracy: 84.87%



Area under the curve = 0.605

Table III: Stratification of diagnostic accuracy for age, gender, and symptom duration.

		Sensitivity	Specificity	PPV	NPV	DA	
Age (years)	30-50	89.43%	83.24%	86.34%	83.65%	85.01%	0.001
	51-70	86.48%	80.87%	83.51%	86.24%	83.69%	0.001
Gender	Male	88.62%	82.49%	84.25%	86.14%	83.0%	0.001
	Female	87.15%	81.96%	85.18%	84.39%	85.43%	0.001
Duration (days)	≤7	87.32%	82.49%	83.28%	85.63%	85.85%	0.001
	>7	88.36%	81.49%	85.75%	85.87%	83.96%	0.001

DISCUSSION

This study assessed the diagnostic precision of carotid Doppler ultrasound in identifying carotid artery stenosis in patients who suffered an ischemic stroke, employing computed tomography as the reference standard. Our study, using computed tomography as the standard, found that carotid Doppler ultrasonography had a sensitivity of 87.65%, a specificity of 81.69%, a PPV of 84.52%, a NPV of 85.29%, and a diagnostic accuracy of 84.87% for finding carotid artery stenosis in people who had an ischemic stroke. Our study's high sensitivity is consistent with research by Salehi et al. from 2021, which found that CDU sensitivity ranged from 85% to 95% for identifying severe carotid artery stenosis in symptomatic people.8

A meta-analysis conducted by Nikolaou et al. (2020) validated our results of a reduced PPV, indicating that CDU is highly effective in detecting ≥70% stenosis, however it may demonstrate subpar performance in mild to moderate stenosis classifications.9 The specificity of 81.69% found in our study is little less than that found in several other studies. Lee et al. found that CDU had a specificity value of about 85% when looking at moderate to severe stenosis, for example.10 The difference may be due to operator dependence in CDU, variances in plaque morphology, and differences in hemodynamics, especially in patients with high bifurcation levels or calcified plaques, which are known to lower Doppler accuracy.11

Our results' high NPV indicates that CDU is especially useful in clinical situations for ruling out severe carotid stenosis. Grant et al. (2019), who highlighted the accuracy of CDU in ruling out significant stenosis in individuals presenting with stroke symptoms, came to similar conclusions.12 In order to avoid overestimating stenosis and avoiding needless procedures, our study's modest PPV supports the necessity of confirmatory CTA in patients with positive CDU findings. Clark et al. (2020) also stressed this point in their meta-analytic assessment.13

Finding out whether or whether an exaggerated CIMT is connected to an exaggerated risk of arteriosclerosis-related events is of significant interest. Arterial cell wall media thickness can be measured using the non-invasive B technique designation, which will aid in early arterial hardening observation and well upset diagnosis.14 In a study of healthy Taiwanese people, males exhibited a significantly greater CIMT than females (0.558 mm vs. actual values mm, P = 0.012). Kablak Ziembicka et al. replicated this effect in patients without Chd (men vs. women 1.05 vs. 0.93 mm, P0.001). In a study, Taiwanese healthy individuals had no CIMT, nor did those without CVD or individuals with conventional aldohexose tolerance.15

Ultrasonography offers a high degree of diagnostic validity and can be used to screen for and detect carotid artery problems, according to several studies. It is strongly recommended to utilize ultrasonography for mass screening and accurately detecting peripheral arterial stenosis because it is a non-invasive, user-

friendly imaging method. It is also trustworthy, safe, and reasonably priced. Furthermore, it has a quite good sensitivity and specificity for screening for carotid stenoses (94.4 percent and 91.7%, respectively).16 Henry and colleagues also say that jugular Duplex scanning is a very good approach to diagnose coronary artery airway obstruction that is more than 70%. It is 96.1% sensitive, 88% specific, 92.5% predictive, 93.6% poor prognostic, and 92.9% accurate overall.16

A study17 found that the diagnostic accuracy of doppler ultrasound is 80%, the overall sensitivity is 91%, the specificity is 77%, the PPV is 47.3%, the NPV is 92.5%. The results of Sardraz S. et al.18 showed that CDU has an overall diagnostic accuracy of 80%, a high sensitivity (91%) and a significant NPV of 92.5%. However, the positive predictive value (PPV) (47.3%) and specificity (77%) indicate significant limitations in accurately ruling out stenosis, particularly in patients with complicated anatomy or borderline conditions. Overall, Ahmad S. et al.7 discovered that Doppler ultrasound has 89.5% sensitivity, 76.20% specificity, 45.5% PPV, 93.88% NPV, and 76.9% diagnostic accuracy.

Furthermore, recent research has demonstrated the advantages of using CDU as a first screening method and CTA for diagnostic confirmation when necessary.19 Particularly in healthcare systems with restricted access to cutting-edge imaging modalities, this methodical approach strikes a compromise between clinical precision and resource utilization. The diagnostic accuracy of CDU may be improved by emerging technologies like contrast-enhanced ultrasonography (CEUS), which may be used in the future.20

All things considered, our findings support the usefulness of CDU as a non-invasive, first-line imaging technique for assessing carotid artery stenosis in patients who have had ischemic stroke. Although CTA's high sensitivity and NPV make it appropriate for screening and exclusion, its limits in specificity and PPV make it necessary to continue using it, especially in situations that are complex or ambiguous. To improve diagnostic yield, more research might concentrate on operator training, applying uniform Doppler criteria, and incorporating cutting-edge ultrasound techniques.

Thes case highlights the importance of a multidisciplinary approach involving neonatology, dermatology, radiology, and paediatric surgery. The association of giant congenital melanocytic nevi with large low-flow vascular malformations is rare, and early diagnosis with coordinated management significantly improves outcomes, both medically and cosmetically.

CONCLUSION

The usefulness of Carotid Doppler Ultrasound as a non-invasive, reasonably priced, and trustworthy screening method for identifying carotid artery stenosis in ischemic stroke patients is highlighted in this study. Particularly in environments with limited resources, CDU can effectively rule out severe stenosis and guide prompt clinical decision-making because to its high sensitivity (87.65%) and negative predictive value (85.29%). Nonetheless, its positive predictive value (84.52%) and reasonable specificity (81.69%) highlight the necessity of confirmation imaging. Future developments in operator education and CDU technology could improve diagnostic accuracy and lessen reliance on more costly or intrusive methods.

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