Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v6i4.1630
*Biol. Clin. Sci. Res. J., Volume 6(4), **2025**: 1630*
Original Research Article

Diagnostic Accuracy of Carotid Doppler Ultrasound for Detection of Carotid Artery Stenosis in Ischemic Stroke Patients: Keeping Computed Tomography Angiography as the Gold Standard

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(Received, 14th March 2025, Accepted 22nd April 2025, Published 30th April 2025)

Abstract: *Carotid artery stenosis is a significant risk factor for ischemic stroke. Early and accurate identification of stenosis is critical for preventing stroke recurrence and improving clinical outcomes. Carotid Doppler Ultrasound (CDU) offers a non-invasive, bedside screening modality, but its diagnostic accuracy compared to Computed Tomography Angiography (CTA) requires further evaluation.* ***Objective:*** *To assess the diagnostic accuracy of CDU in detecting carotid artery stenosis in ischemic stroke patients, CTA was used as the reference standard.* ***Methods:*** *This diagnostic accuracy study was conducted at Combined Military Hospital (CMH), Kharian, and included 95 patients with ischemic stroke who underwent both CDU and CTA. CDU was performed by experienced sonographers, assessing stenosis using peak systolic velocity and intima-media thickness. CTA was interpreted by radiologists blinded to CDU findings. The diagnostic performance of CDU was measured in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy, with CTA serving as the gold standard.* ***Results:*** *Among the 95 patients, CDU demonstrated a sensitivity of 91%, specificity of 77%, PPV of 47.3%, NPV of 92.5%, and overall diagnostic accuracy of 80%. CDU showed strong performance in identifying patients without significant stenosis but had moderate specificity in confirming the presence of stenosis.* ***Conclusion:*** *CDU is a valuable screening tool for carotid artery stenosis in ischemic stroke patients, particularly in settings with limited access to advanced imaging. However, confirmatory CTA remains necessary for definitive diagnosis due to its limited specificity and PPV. When supported by appropriate follow-up imaging, integrating CDU into stroke workups can enhance early detection and streamline care pathways.*

Keywords: Carotid artery stenosis, Doppler ultrasound, Ischemic stroke, CTA, Diagnostic accuracy, Screening tool

[***How to Cite:*** Sarfraz S, Muhammad D, Khan MB, Sanaullah, Sarshar S**,** Itrat Z. Diagnostic accuracy of carotid doppler ultrasound for detection of carotid artery stenosis in ischemic stroke patients: keeping computed tomography angiography as the gold standard. *Biol. Clin. Sci. Res. J.*, **2025;** 6(4): 37-39. doi: https://doi.org/10.54112/bcsrj.v6i4.1630

Introduction

Ischemic stroke remains a major global health concern, contributing significantly to morbidity and mortality. It accounts for approximately 75–85% of all stroke cases, with hemorrhagic and subarachnoid hemorrhages comprising the remainder (1). In South Asia, including Pakistan, the burden of stroke is rising due to increased prevalence of atherosclerotic risk factors such as hypertension, diabetes mellitus, dyslipidemia, and smoking (2, 3). A significant proportion of ischemic strokes are attributable to extracranial carotid artery stenosis, particularly at the carotid bifurcation (4).

Early detection and management of carotid artery stenosis is critical to reduce the risk of recurrent stroke and transient ischemic attacks (TIAs). Carotid Doppler Ultrasonography (CDU) is a widely used, non-invasive, cost-effective, and radiation-free imaging modality that provides real-time assessment of blood flow dynamics and vessel morphology (5). However, operator expertise, patient anatomy, and technical limitations can influence its diagnostic performance, particularly in calcified plaques or high bifurcations (6).

Computed Tomography Angiography (CTA), in contrast, is considered the gold standard for non-invasive evaluation of carotid stenosis due to its high spatial resolution, rapid acquisition, and ability to assess both luminal and wall characteristics(7). Nevertheless, CTA carries the disadvantages of ionizing radiation exposure and nephrotoxic contrast medium, making it less suitable for some patient populations (8).

Several studies have investigated the diagnostic accuracy of CDU compared with CTA in detecting clinically significant carotid artery stenosis. Reported sensitivity of CDU ranges from 85% to 95%, while specificity can vary depending on the velocity thresholds and degree of stenosis assessed (9-11). A combination of CDU as a first-line screening tool followed by CTA in selected cases has been proposed to optimize diagnostic yield and resource allocation (12).

In Pakistan, there is a scarcity of local data evaluating the diagnostic accuracy of CDU in ischemic stroke patients using CTA as the reference standard. This study aims to fill this gap by assessing CDU's sensitivity, specificity, and predictive values in detecting carotid artery stenosis in patients with ischemic stroke, thus informing evidence-based imaging protocols in resource-limited healthcare settings.

Methodology

This prospective diagnostic accuracy study was conducted at Combined Military Hospital (CMH), Kharian, to assess the diagnostic performance of Carotid Doppler Ultrasound (CDU) in detecting carotid artery stenosis in ischemic stroke patients, using Computed Tomography Angiography (CTA) as the reference standard. The study duration was from September 2024 to February 2025, and ethical approval details were appropriately considered, and informed written consent was obtained from all participants before inclusion.

A total of 95 patients diagnosed with ischemic stroke were enrolled. Inclusion criteria included patients who underwent CDU and CTA imaging to evaluate carotid artery stenosis. Patients with incomplete imaging data or those who had not undergone both modalities were excluded to ensure uniform comparison across the cohort.

All participants underwent CDU performed by experienced sonographers using high-resolution ultrasound machines. CDU assessments were based on established diagnostic criteria, including evaluation of peak systolic velocity (PSV), intima-media thickness, and luminal narrowing. CDU results were classified based on stenosis severity according to validated PSV and end-diastolic velocity thresholds.

Subsequently, CTA of the carotid arteries was performed using a multidetector CT scanner. CTA imaging was interpreted by board-certified radiologists trained in vascular imaging, blinded to CDU results. Quantitative stenosis assessment was performed on axial and multiplanar reconstructed images, measuring the percentage reduction in luminal diameter by the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria.

The primary outcome measures included sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of CDU compared to CTA. Data were compiled and analyzed using SPSS version 2022, and diagnostic accuracy metrics were calculated using 2×2 contingency tables.

Results

A total of 95 patients diagnosed with ischemic stroke were included in the study. Among them, 58 (61.05%) were males and 42 (39.00%) were females, as shown in Table, Figure 1.

The mean age of participants was 52.11 ± 8.40 years. The average body mass index (BMI) was 24.1 ± 13.25 kg/m², and the mean disease duration was 1.7 ± 6.34 years (Table 2).

Regarding the diagnostic performance of Carotid Doppler Ultrasound (CDU) when compared with Computed Tomography Angiography (CTA) as the gold standard, CDU demonstrated a high sensitivity of 91% and a negative predictive value (NPV) of 92.5%, indicating its strength in ruling out carotid artery stenosis. However, its specificity was 77%, and the positive predictive value (PPV) was relatively lower at 47.3%, leading to a diagnostic accuracy of 80% (Table 3).

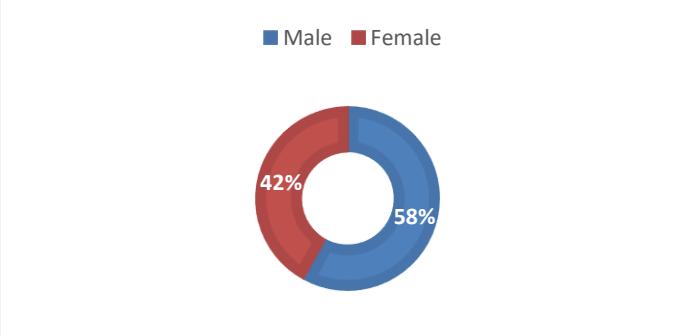

Figure 1: Distribution of gender

Table 1: Gender Distribution

Gender	Frequency	Percentage (%)
Male	58	61.05
Female	42	39

Table 2: Baseline Characteristics

Variable	Value
Mean Age (years)	52.11 ± 8.40
Mean BMI (kg/m²)	24.1 ± 13.25
Mean Duration of Disease (years)	1.7 ± 6.34

Table 3: Diagnostic Accuracy Parameters of CDU

Diagnostic Metric	Value (%)
Sensitivity	91
Specificity	77
Positive Predictive Value	47.3
Negative Predictive Value	92.5
Diagnostic Accuracy	80

Discussion

This study evaluated the diagnostic accuracy of Carotid Doppler Ultrasound (CDU) in identifying carotid artery stenosis among ischemic stroke patients, using Computed Tomography Angiography (CTA) as the gold standard. Our findings demonstrate that CDU has a high sensitivity (91%) and a strong negative predictive value (NPV) of 92.5%, with an overall diagnostic accuracy of 80%. However, the specificity (77%) and positive predictive value (PPV) (47.3%) suggest some limitations in precisely ruling out stenosis, especially in borderline or complex anatomical cases.

The high sensitivity observed in our study aligns with findings from a 2021 study by Salehi et al., who reported CDU sensitivity ranging between 85% and 95% for detecting significant carotid artery stenosis in symptomatic individuals (13). Similarly, a meta-analysis conducted by Nikolaou et al. 2020 confirmed that CDU is highly sensitive in identifying ≥70% stenosis but may underperform in mild to moderate stenosis categories, consistent with our observed lower PPV (14).

Our study's specificity of 77% is slightly lower than that reported in some literature. For example, Lee et al. (2020) reported specificity values of around 85% for CDU when assessing moderate to severe stenosis (15). The discrepancy may be attributed to operator dependency in CDU, variation in plaque morphology, and hemodynamic differences, particularly in patients with calcified plaques or high bifurcation levels, which are known to impair Doppler accuracy (16).

The strong NPV in our findings suggests that CDU is particularly valuable in excluding significant carotid stenosis in clinical settings. Similar conclusions were drawn by Grant et al. (2019), who emphasized the reliability of CDU for ruling out critical stenosis in patients presenting with stroke symptoms (17). The moderate PPV observed in our study, however, supports the need for confirmatory CTA in patients with positive CDU findings, to prevent overestimation of stenosis and avoid unnecessary interventions—a recommendation also emphasized by Clark et al. (2020) in their meta-analytic evaluation(18).

Moreover, recent studies have highlighted the benefit of integrating CDU as an initial screening tool followed by CTA for diagnostic confirmation when required (19). This sequential approach balances resource utilization and clinical accuracy, especially in healthcare systems with limited access to advanced imaging modalities. Emerging technologies such as contrast-enhanced ultrasound (CEUS) have also shown promise in improving CDU's diagnostic precision and could be considered for future application (20).

Overall, our results reinforce CDU's value as a first-line, non-invasive imaging modality for evaluating carotid artery stenosis in ischemic stroke patients. While its high sensitivity and NPV make it suitable for screening and exclusion purposes, limitations in specificity and PPV necessitate the continued use of CTA, particularly in complex or equivocal cases. Further studies may focus on operator training, implementation of standardized Doppler criteria, and integration of advanced ultrasound techniques to enhance diagnostic yield.

Conclusion

This study highlights the utility of Carotid Doppler Ultrasound (CDU) as a non-invasive, cost-effective, and reliable screening tool for detecting carotid artery stenosis in patients with ischemic stroke. With a high

sensitivity (91%) and excellent negative predictive value (92.5%), CDU effectively rules out significant stenosis and can guide timely clinical decision-making, particularly in resource-constrained settings. However, its moderate specificity (77%) and low positive predictive value (47.3%) underscore the need for confirmatory imaging, such as Computed Tomography Angiography (CTA), especially in cases with suspected high-grade or ambiguous stenosis. Future advancements in CDU technology and operator training may enhance diagnostic precision and reduce dependency on more invasive or expensive modalities.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned. (IRBEC-A/24/17)
Consent for publication
Approved
Funding
Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

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