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ROLE OF DOPPLER ULTRASOUND AND CT-ANGIOGRAPHY IN EVALUATION OF PERIPHERAL ARTERIAL DISEASE

Original Research

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ABSTRACT

Background: Peripheral arterial disease (PAD) is a progressive atherosclerotic condition that compromises arterial blood flow, particularly to the lower limbs, leading to significant morbidity. Early and accurate diagnosis is essential for timely intervention and prevention of complications such as ulcers, claudication, and limb loss. Non-invasive imaging techniques like Doppler ultrasonography (DS) and computed tomography angiography (CTA) are critical in evaluating the extent and severity of PAD.

Objective: To evaluate and compare the diagnostic accuracy, strengths, and limitations of Doppler ultrasonography and CT angiography in assessing peripheral arterial disease, and to determine their combined utility in patient management.

Methods: A prospective cross-sectional study was conducted at the Department of Radiology, PAF Hospital Islamabad, between July and December 2024. A total of 255 patients (175 males, 80 females) with suspected PAD were enrolled using a non-probability consecutive sampling technique. Each participant underwent both DS and CTA as part of their diagnostic workup. Data including demographics, imaging findings, and stenosis grading were recorded. Kappa statistics were applied to assess inter-modality agreement, while diagnostic performance metrics—sensitivity, specificity, PPV, NPV, and accuracy—were calculated using SPSS version 25.

Results: Of 255 individuals, 84 were found positive on DS and 171 on CTA. CTA identified wall thickness in 28.7% of cases, wall calcification in 26.3%, occlusion in 24.0%, and thrombus in 21.1%. In comparison, DS detected 59.5% wall thickness, 15.5% wall calcification, 13.1% occlusion, and 11.9% thrombus. Sensitivity and specificity of DS were 49.1% and 100%, respectively, with an overall diagnostic accuracy of 65.9%. CTA demonstrated superior detection in moderate-to-severe stenosis grades.

Conclusion: Doppler ultrasound remains valuable for initial PAD screening, particularly in early disease stages. However, CTA is essential for detailed vascular mapping and treatment planning in advanced cases. A combined diagnostic approach enhances accuracy and optimizes patient care.

Keywords: Angiography, Atherosclerosis, Computed Tomography, Doppler Ultrasound, Peripheral Arterial Disease, Sensitivity and Specificity, Vascular Imaging.

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INTRODUCTION

Peripheral arterial disease (PAD) is a common yet often underdiagnosed vascular condition that arises due to the progressive narrowing or complete obstruction of large and medium-sized arteries, predominantly as a result of atherosclerosis. This narrowing restricts blood flow and oxygen delivery to peripheral tissues, most notably affecting the lower limbs. The clinical manifestations of PAD vary in severity but often include intermittent claudication—pain, cramping, or fatigue in the calf muscles during ambulation, which typically subsides with rest—as well as non-healing ulcers, skin discoloration, and in advanced stages, gangrene (1). PAD predominantly affects individuals over the age of 50, and its progression is accelerated by modifiable risk factors such as smoking, diabetes mellitus, hypertension, hyperlipidemia, obesity, and physical inactivity (2). Despite being a major cause of functional decline and reduced quality of life in older adults, PAD remains under-recognized in clinical practice, often delaying diagnosis and appropriate intervention. The burden of PAD not only impacts physical health but is also associated with an increased risk of cardiovascular morbidity and mortality. Early and accurate diagnosis is, therefore, essential to initiate timely management and to prevent complications such as critical limb ischemia and amputation (3,4). While clinical examination and symptomatology offer initial insights, diagnostic confirmation relies heavily on imaging modalities that evaluate arterial patency and structural integrity. Color Doppler ultrasonography remains a first-line, non-invasive tool that assesses blood flow dynamics and localizes stenotic segments through high-frequency sound waves (5). However, its diagnostic accuracy may be limited in patients with extensive vascular calcifications or deep-seated vessels. In contrast, multidetector computed tomography (MDCT) angiography offers superior spatial resolution, generating detailed three-dimensional reconstructions of the arterial tree, enabling better visualization of calcifications, wall thickening, and collateral formations (6,7). Recent evidence suggests that MDCT angiography may surpass Doppler ultrasound in delineating the extent and nature of atherosclerotic disease, thereby aiding in more precise treatment planning (8,9).

In a comparative study conducted in 2015 involving 30 patients with clinically suspected PAD, both color Doppler ultrasonography and MDCT angiography were employed for diagnostic assessment. The findings demonstrated a significant difference in diagnostic efficacy, with MDCT angiography proving more sensitive in detecting vascular abnormalities, especially in terms of calcific plaques and collateral vessel development (10,11). As imaging technologies continue to evolve, there remains a critical need to evaluate the relative diagnostic strengths of these modalities in diverse patient populations. This study, therefore, aims to compare the diagnostic performance of color Doppler ultrasonography and MDCT angiography in patients with peripheral arterial disease, with the objective of identifying the most effective tool for early and accurate diagnosis to inform clinical decision-making and optimize patient outcomes.

METHODS

A prospective cross-sectional study was conducted at the Department of Radiology, PAF Hospital Islamabad (Unit-II) over a six-month period from July to December 2024. Ethical approval was granted by the Institutional Review Board of PAF Hospital (Application No. 240722), ensuring compliance with ethical standards for human research. Informed consent was obtained from all participants prior to inclusion in the study. The sample size was calculated using the WHO sample size calculator based on the formula $n = z^2p(1-p)/\varepsilon^2$, using a previously reported prevalence of 21% for peripheral arterial findings (PAF) in peripheral pulses, at a 95% confidence interval and a 5% margin of error. This yielded a target sample size of 255 patients. A non-probability consecutive sampling technique was used to enroll participants who met the inclusion criteria. Patients were eligible if they were suspected of having peripheral arterial disease (PAD) and had undergone both Doppler ultrasound and computed tomography angiography (CTA) as part of their clinical workup. Patients with a history of peripheral arterial intervention or surgery were excluded to minimize confounding from pre-existing alterations in vascular anatomy (12,13). Data were retrospectively extracted from electronic medical records and imaging archives. Demographic details such as age and sex, clinical symptoms, and relevant laboratory parameters were recorded. Imaging findings from both Doppler ultrasound and CTA were independently reviewed by two experienced radiologists who were blinded to each other's assessments to reduce observer bias. The primary radiological parameters evaluated included arterial wall thickness, wall calcification, presence of occlusion, and intraluminal thrombosis. Arterial stenosis was graded based on luminal narrowing as follows: Grade 0 (normal), Grade 1 (0–50%), Grade 2 (50–75%), Grade 3 (>75%), and Grade 4 (complete occlusion or thrombus). Data analysis was performed using SPSS version 25. Quantitative variables were summarized using means and standard deviations, while categorical variables were

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expressed as frequencies and percentages. Inter-modality agreement between Doppler sonography and CTA was assessed using Cohen's Kappa statistics, with kappa values interpreted to determine the strength of agreement. Diagnostic performance metrics including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy for both imaging modalities were calculated using standard formulas. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 255 individuals were included in the study, comprising 175 males and 80 females. The patients were assessed using both Doppler sonography and computed tomography angiography for the diagnosis of peripheral arterial disease. Among them, 84 patients were found to have positive findings on Doppler sonography, while 171 patients demonstrated abnormalities on CT angiography. The analysis of segmental findings revealed significant differences between the two diagnostic modalities. Among the Doppler sonography-positive segments, wall thickness was observed in 59.5% (n=50), wall calcification in 15.5% (n=13), occlusion in 13.1% (n=11), and thrombosis in 11.9% (n=10). In comparison, CT angiography detected wall thickness in 28.7% (n=49), wall calcification in 26.3% (n=45), occlusion in 24.0% (n=41), and thrombosis in 21.1% (n=36). The differences in detection between the two modalities were statistically significant with a p-value of less than 0.05. Grading of arterial stenosis showed that 97 segments (38.0%) were classified as Grade 1 (mild stenosis, 0–50%), 71 segments (27.8%) as Grade 2 (moderate stenosis, 50–75%), 46 segments (18.0%) as Grade 3 (severe stenosis, >75%), and 41 segments (16.1%) as Grade 4 (occlusion or thrombus). Among specific arterial regions, the most commonly involved sites on CT angiography included the posterior tibial artery, profunda artery, and common iliac artery. Comparatively, Doppler sonography showed fewer detections in higher grades of stenosis, particularly in occlusions and thrombosis, reinforcing the diagnostic superiority of CT angiography in advanced PAD. The diagnostic performance analysis revealed that Doppler sonography demonstrated a sensitivity of 49.1% and a specificity of 100% when compared with CT angiography as the reference standard. The positive predictive value (PPV) was 100%, indicating that all segments identified as positive on Doppler were indeed true positives. However, the negative predictive value (NPV) was 49.1%, suggesting a substantial proportion of missed cases by Doppler sonography that were later confirmed on CT angiography. The overall diagnostic accuracy of Doppler sonography in detecting peripheral arterial disease was 65.9%. These findings underscore the high reliability of Doppler in confirming disease presence but also highlight its limitations in excluding PAD, reinforcing the role of CT angiography as a superior diagnostic modality in comprehensive vascular assessment.

Table 1: Grading of Stenosis

Grades	Criteria
Grade-0	NORMAL PATENCY
Grade-1	MILD STENOSIS (0-50%)
Grade-2	MODRATE STENOSIS (50-75%)
Grade-3	SEVERE STENOSIS (>75%)
Grade-4	OCCLUSION, THROMBUS

Table 2: The Distribution of PAD

Segments	DS positive	CT- angiography
wall thickness	50(59.5%)	49(28.7%)
wall calcification	13(15.5%)	45(26.3%)
occlusion	11(13.1%)	41(24.0%)
thrombosis	10(11.9%)	36(21.1%)
Total	84	171

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Table 3: Total segment involved and their stenosis

Segments	PAD Positive	Grading's			
		Grade-1	Garde-2	Grade-3	Grade-4
Infrarenal Aorta	CTA	2	1	2	1
	DS	3	2	2	0
ATA	CTA	6	4	7	2
	DS	3	2	1	0
CFA	CTA	6	8	4	3
	DS	4	5	2	1
CIA	CTA	7	3	4	2
	DS	4	2	1	1
DFA	CTA	4	2	0	1
	DS	2	2	1	0
DPA	CTA	5	3	4	3
	DS	4	2	0	0
EIA	CTA	7	4	1	1
	DS	5	3	1	0
IIA	CTA	4	5	1	2
	DS	1	2	1	1
PA	CTA	7	6	2	6
	DS	4	3	1	2
PTA	CTA	6	4	7	9
	DS	4	2	0	0
SFA	CTA	6	3	4	2
	DS	3	3	0	4
Total	255(100%)	97(38.0%)	71(27.8%)	46(18.0%)	41(16.1%)

Table 4: Diagnostic Performance of Doppler Sonography

Metric	Value
Sensitivity	0.491
Specificity	1
Positive Predictive Value (PPV)	1
Negative Predictive Value (NPV)	0.491
Diagnostic Accuracy	0.659

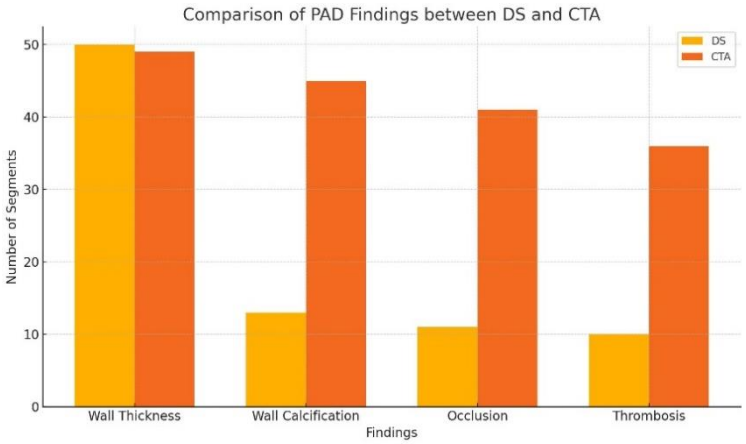

Figure 1 Comparison of PAD Findings between DS and CTA

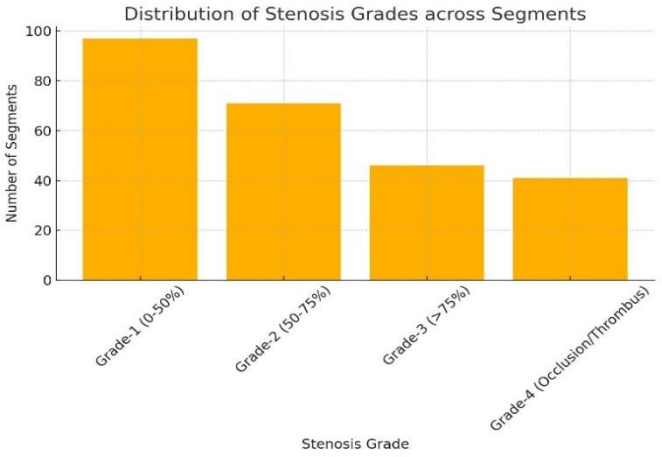

Figure 2 Distribution of Stenosis Grades Across Segments

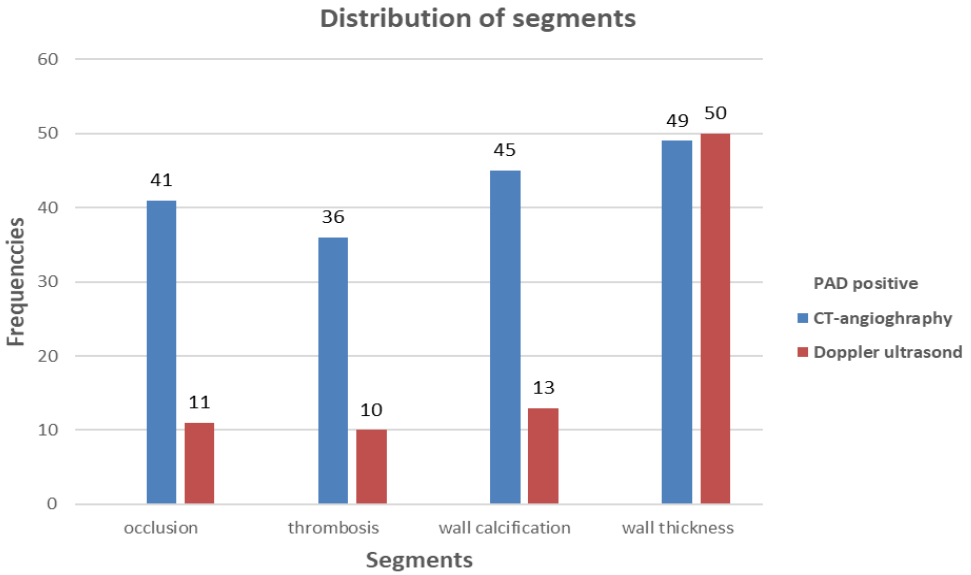

Figure 3 Distribution of Segments

DISCUSSION

The findings of this study underscore the critical role of both Doppler ultrasound (DS) and computed tomography angiography (CTA) in the diagnostic evaluation of peripheral arterial disease (PAD). CTA consistently demonstrated superior diagnostic performance, particularly in identifying advanced vascular pathology, including arterial wall calcifications, thrombosis, and complete occlusions. These observations are in alignment with previous literature, which has similarly shown that CTA provides greater sensitivity and spatial resolution, especially in moderate-to-severe stenotic lesions (14). The use of Kappa statistics revealed a moderate agreement between the two imaging modalities, highlighting that DS and CTA serve complementary functions in clinical practice. Doppler ultrasound remains a highly accessible and cost-effective first-line imaging modality, offering the advantage of being non-invasive and free from ionizing radiation. In this study, DS exhibited acceptable diagnostic agreement in early disease stages (Grades 0 and 1), which supports its utility in initial screening and hemodynamic assessment (15,16). Its real-time evaluation of blood flow further enhances its value in

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serial monitoring and follow-up of PAD patients. However, its diagnostic limitations became more apparent in advanced disease stages. The reduced sensitivity in detecting calcified or occluded vessels, along with its operator dependency, may result in underdiagnosis or mischaracterization of disease severity. These limitations are consistent with those previously reported in vascular imaging research (17,18).

On the other hand, CTA demonstrated higher detection rates in Grades 2, 3, and 4 stenosis, proving indispensable in preoperative mapping and treatment planning. The ability to generate three-dimensional reconstructions facilitates precise anatomical visualization, particularly in complex or multisegmented diseases. Despite these advantages, concerns remain regarding CTA's exposure to ionizing radiation and the risk of contrast-induced nephropathy, especially in patients with preexisting renal impairment. These drawbacks limit its routine use as a first-line diagnostic modality, reinforcing the need for selective use based on initial clinical and Doppler findings (19).

One of the strengths of this study lies in its prospective design, standardized imaging assessment, and comparative analysis involving a relatively large sample size. Both imaging modalities were interpreted by independent radiologists, which minimized bias and enhanced reliability. The use of Kappa statistics and the calculation of diagnostic performance metrics further reinforced the validity of the findings. Nevertheless, certain limitations must be acknowledged. The study was conducted at a single center, which may affect the generalizability of results. Additionally, the reliance on retrospective record extraction for clinical and imaging data could have introduced information bias. Another limitation was the absence of invasive angiographic confirmation, which is considered the gold standard, to validate the findings of CTA and DS. Future studies should explore the integration of advanced technologies such as artificial intelligence to automate and enhance image interpretation, thereby reducing operator dependency and inter-observer variability. Moreover, optimization of low-dose CT protocols should be prioritized to mitigate radiation exposure while preserving diagnostic accuracy (20). A multimodal imaging approach that begins with DS and selectively incorporates CTA for equivocal or complex cases represents a rational and clinically efficient strategy for PAD diagnosis. Such stratified imaging pathways not only enhance diagnostic precision but also reduce unnecessary healthcare costs and patient risk.

CONCLUSION

This study concludes that Doppler ultrasound remains a valuable first-line imaging modality for the initial assessment of peripheral arterial disease, particularly effective in early stages where mild stenosis is present. However, for more advanced cases, computed tomography angiography proves essential in accurately identifying complex arterial lesions and guiding therapeutic decision-making. The complementary use of both modalities offers a practical and effective diagnostic pathway, enhancing overall precision in disease detection and enabling more informed clinical management. Adopting a combined imaging strategy can significantly improve patient outcomes by ensuring timely and targeted interventions.

AUTHOR CONTRIBUTION

Author	Contribution
Auroosh Sagheer	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Shaista Nayyar	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Sundas Yaseen*	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Sohaib Khalid	Contributed to Data Collection and Analysis

Author	Contribution
	Has given Final Approval of the version to be published
Shahzeb Jawwad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Shaheryar Toor	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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