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COMPARATIVE STUDY OF DOPPLER AND CT ANGIOGRAPHY IN PERIPHERAL ARTERIAL DISEASE IN DIABETICS

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Abstract

Background: *Peripheral artery disease (PAD) is common and serious side effect of diabetes. It often takes long time to diagnose and raises risk of limb ischemia and amputation. Doppler ultrasound (DUS) is widely used non-invasive modality. While CT angiography shows blood vessels more clearly but it costs more and exposes patient to radiations.*

Objective: *Aim of this study are to: (1) identify diagnostic values of DUS and CT angiography in assessment of PAD and (2) compare and contrast their strengths and limitations.*

Methodology: *This prospective cross-sectional study was conducted at a Tertiary Care hospital in Rawalpindi from July 2024 to December 2024. Diabetic patients suspected of having PAD, were enrolled. All patients underwent DUS followed by CT angiography. Lower limb arterial segments including aorto-iliac, femoral and tibial regions were evaluated for stenosis severity. Diagnostic performance of Doppler ultrasound was assessed in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic accuracy with CT angiography.*

Results: *Sixty diabetic patients diagnosed with PAD. Average age was 43.47±12.15 years, 71.7% of them were men. 61.7% of patients had diabetes for at least 10 years and 73.3% of patients did not have good glycemic control (HbA1c ≥7%). 76% percent of people had PAD symptoms for at least six months. Hypertension (78.3%) was most common risk factor. CT angiography found more severe stenosis than DUS, especially grade 4 stenosis (15.0% vs. 11.7%) and distal tibial stenosis (grade 3: 18.3% on CT vs. 13.3% on Doppler). When CT angiography was utilized as gold standard, DUS was quite accurate, with sensitivity of 92.9% in aorto-iliac region, 95.8% in femoral region and 96.0% in tibial region.*

***Conclusion**: DUS for preliminary screening of PAD remains reliable and valuable approach, particularly in early stages in diabetics. In more intricate cases, CT angiography remains superior. Combining both techniques yield optimal patient care and enhanced accuracy.*

INTRODUCTION

Patients with diabetes mellitus are increasingly experiencing complications that are related to peripheral arterial disease (PAD). Primary causes including systemic atherosclerosis, endothelial dysfunction and chronic metabolic disorders, may accelerate vascular aging and induce obstructions.[1] PAD in diabetics significantly increases risk of critical limb ischemia and lower-extremity amputation. PAD in diabetics also worsening cardiovascular morbidity and mortality. Accurate and immediate detection is essential to effectively manage disease prognosis. Diabetics may exhibit various clinical symptoms owing to concurrent peripheral neuropathy that obscure typical intermittent claudication and postpone clinical diagnosis.[2]

Doppler ultrasound (DUS) is non-invasive imaging modality for evaluation of PAD. This is because to its accessibility, absence of ionizing radiation and its ability to reveal changes in blood flow dynamics and velocity that may signify stenosis or occlusion. Recent meta-analyses indicated high sensitivity (80%) and specificity (95%) of DUS in detecting significant peripheral arterial lesions, particularly in larger vessels such as femoropopliteal segment. Accuracy might be effected in smaller or calcified arteries frequently associated with diabetes.[3] Diagnostic efficacy of DUS is significantly influenced by operator and may be diminished by patient-specific variables including obesity, edema, arterial calcification and intricate anatomical anomalies that can obscure spectral waveforms and impede detection of stenotic segments.[4]

Computed tomography (CT) angiography, offers comprehensive 3D representation of vascular network. Recent comparative investigations of PAD in diabetic populations have demonstrated superiority of CT angiography to DUS. It revealed superior sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) to detect ≥50% stenosis in aortoiliac, femoropopliteal and infrapopliteal regions. This renders it particularly advantageous for distant vascular assessments while DUS may be less effective.[5]

When comparing DUS to CT angiography, often detects greater number of lesions, particularly in early stages of PAD in diabetics. In cases of lower limb PAD, CT angiography is superior to detect mild-moderate stenotic alterations that DUS may overlook. Nonetheless, two approaches yield more comparable results in cases with significant stenosis or occlusion.[6] This contrast indicated that CT angiography excels in creating detailed anatomical maps, essential for planning surgeries and procedures involving blood arteries. DUS provides real-time data regarding blood flow that may influence immediate and long-term decision-making.[7] High diagnostic accuracy and reproducibility of CT angiography render it an excellent reference modality for assessing PAD. However, because of utilization of ionizing radiation and iodinated contrast, it may cause complications for diabetics with chronic kidney disease or those allergic to contrast agents.[8]

Recent retrospective and prospective studies increasingly endorsed complementary diagnosis strategy that utilizes advantages of both modalities: DUS is employed for initial assessment and functional hemodynamic evaluation. Followed by CT angiography for conclusive anatomic characterization when clinical inquiries arise or when revascularization planning commences.[9]

Aim of this study was to evaluate how well DUS and CT angiography can detect PAD in diabetics. For this purpose, both imaging modalities were compared to assess diagnostic accuracy. Ultimately, it seeks to provide guidance on their optimal clinical utilization in diabetic patients.

METHODOLOGY

Prospective cross-sectional study was conducted at a Tertiary Care hospital in Rawalpindi from July 2024 to December 2024. Written informed consent was obtained from all participants after explaining study objectives, potential risks, and benefits.

Sample size was estimated using WHO sample size calculator, assuming 95% confidence interval, expected sensitivity of 81% for DUS and 100% for CT angiography and test power of

95%, minimum required sample size was calculated to be 60 patients. Non-probability consecutive sampling technique was used to enroll patients who met inclusion criteria. All participants had both DUS and CT angiography of lower limbs in rapid succession to minimize temporal fluctuations in arterial condition.

Patients aged 18–75 years old, diagnosed with Type 1 or Type 2 diabetes mellitus, willing to undergo both DUS and CT angiography and clinically suspected for PAD (e.g., intermittent claudication, rest pain, non-healing ulcers or diminished peripheral pulses) and willing to undergo both DUS and CT angiography, were included. Any patient with known allergy to iodinated contrast media, pregnant or lactating women, incomplete clinical or imaging data, renal impairment contraindicating contrast use (e.g., serum creatinine > 1.5 mg/dL) or history of prior lower limb vascular surgery and stenting to minimize confounding from pre-existing alterations, were excluded.

High-frequency linear transducer was used to perform DUS testing on common aorto-iliac, femoral and tibial regions. Skilled sonographer, who did not know CT angiography findings, wrote down stenosis or occlusion's presence, location and severity.

CT angiography was done with typical contrast delivery approach on multidetector CT scanner. Images were rebuilt in axial, coronal and sagittal planes and 3D volume-rendered images were made so that we could see them in more detail. Radiologist examined images independently and documented severity of stenosis and anatomical distribution.

Statistical Package for the Social Sciences (SPSS), version 25.0, was used to clean and analyze data. Continuous data was expressed as mean ± standard deviation, whereas categorical variables were provided in frequencies and percentages. Descriptive statistics were used to summarize demographic data, clinical features, risk factors and distribution of vascular involvement. DUS vs CT angiography was divided into groups based on parts of arteries, like aorto-iliac, femoral and tibial areas. After that, they were ranked according to how severe stenosis was. Cross-tabulation was employed to compare stenosis grades identified by DUS with those detected by CT angiography. CT angiography was considered gold standard for diagnostic evaluation. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and overall diagnostic accuracy (DA) of DUS for each arterial segment was determined. Results of Doppler ultrasonography and CT angiography were compared to assess how reliable DUS is for finding PAD.

RESULTS

This study included 60 diabetic patients diagnosed with PAD. The average age of patients was 43.47±12.15 years. Most of the patients were men with an average age of 44.09±13.01 years. The average age of women was 41.89±9.81 years. The majority of patients (61.67%) had diabetes for extended duration ≥ 10 years. 73.33% of patients had HbA1c levels of ≥ 7%, which showed that their blood sugar levels were not effectively controlled. 76% of patients had PAD symptoms for at least 6 months. The most prevalent risk factor was high blood pressure which was present in 78.33% of patients followed by neuropathy (28.33%), nephropathy (25.00%), dyslipidemia (20.00%) and retinopathy (16.67%) followed. 10% of patients had chronic kidney disease (CKD) and 10% had coronary artery disease (CAD). 6% of patients had cerebrovascular illness, represented in Table 1. Right lower limb stenosis was more prevalent with 45.00% of patients displaying evidence of it. In 31.67% of cases, both limbs were afflicted, while in 23.33% of cases, just the left lower limb was affected, shown in Table 2.

In Table 3, Doppler ultrasonography revealed no stenosis in 56.67% of patients inside the aorto-iliac region while CT angiography indicated no stenosis in 55.00% of patients. CT angiography was better to find greater grades of stenosis, notably grade 4 stenosis (15.00% on CT angiography vs 11.67% on Doppler). Doppler revealed no stenosis in 61.67% of patients in the femoral region but CT angiography indicated no stenosis in 60.00% of instances. Doppler detected grade 3 stenosis in 13.33% of patients in

the tibial region. CT angiography identified higher proportions of grade 3 and grade 4 stenosis, 18.33% and 8.33%, respectively. This indicated that CT angiography is more effective in displaying advanced disease in distal arteries.

In Table 4, doppler demonstrated commendable diagnostic accuracy across all arterial segments when compared to CT angiography, keeping as gold standard. In the aorto-iliac area, Doppler was 92.86% sensitive and 100% specific. It had 100% positive predictive value (PPV) and 94.12% negative predictive value (NPV). Examinations were correct 96.67% of the time. Sensitivity and specificity in the femoral region were 95.83% and 100%, respectively, while the diagnostic accuracy (DA) was 98.33%. In the tibial area, Doppler also exhibited a sensitivity of 96.00%, specificity of 100% and DA of 98.33%. These findings indicated that Doppler ultrasound and CT angiography are effective in detecting and assessing PAD in patients with diabetes. CT angiography detects markedly higher degrees of stenosis, particularly in distal arterial segments.

Table 1. Descriptive Statistics and Frequency of Risk Factors of PAD in Diabetics Patients (n = 60)

Variables	Value
Age (Mean±SD)	43.47±12.15
Gender (Mean±SD)	
Male (n = 43)	44.09±13.01
Female (n = 17)	41.89±9.81
Duration of Diabetes; n (%)	
< 10 Years	23 (38.33%)
≥ 10 Years	37 (61.67%)
Glycemic Control (HbA1c); n (%)	
< 7 %	16 (26.67%)
≥ 7 %	44 (73.33%)
Duration of PAD; n (%)	
< 6 Months	14 (23.33%)
≥ 6 Months	46 (76.67%)
Risk Factors; n (%)	
Neuropathy	17 (28.33%)
Nephropathy	15 (25.00%)
Retinopathy	10 (16.67%)
Hypertension	47 (78.33%)
Dyslipidemia	12 (20.00%)
CAD	6 (10.00%)
Cerebrovascular Disease	4 (6.67%)
CKD	6 (10.00%)

PAD: Peripheral Arterial Disease; SD: Standard Deviation; CAD: Coronary Artery Disease; CKD: Chronic Kidney Disease

Table 2. Limbs Involved in PAD in Diabetes Patients (n = 60)	
Limbs	**Value; n (%)**
Left Lower Limb	14 (23.33%)
Right Lower Limb	27 (45.00%)
Bilateral Limbs	19 (31.67%)

Table 3. Cases Distribution in Different Regions Involved in PAD in Diabetes Patients (n = 60)					
Stenosis Severity Grade					
Modality; n (%)	0	1	2	3	4
Aorto-Iliac Region					
Doppler	34 (56.67%)	5 (8.33%)	8 (13.33%)	6 (10.00%)	7 (11.67%)
CT Angiography	33 (55.00%)	3 (5.00%)	11 (18.33%)	4 (6.67%)	9 (15.00%)
Femoral Region					
Doppler	37 (61.67%)	4 (6.67%)	9 (15.00%)	6 (10.00%)	4 (6.67%)
CT Angiography	36 (60.00)	2 (3.33%)	11 (18.33%)	7 (11.67%)	4 (6.67%)
Tibial Region					
Doppler	36 (60.00%)	2 (3.33%)	10 (16.67%)	8 (13.3%)	4 (6.67%)
CT Angiography	35 (58.33%)	1 (1.67%)	8 (13.33%)	11 (18.33%)	5 (8.33%)

Table 4. 2×2 Contingency Table of Doppler vs CT Angiography, Degree of Stenosis in PAD in Diabetes Patients (n = 35)			
Doppler (n, %)	**CT Angiography (n, %)**		
	Aorto-Iliac Region		
	Positive	**Negative**	Sensitivity = 92.86% Specificity = 100% PPV = 100% NPV = 94.12% DA = 96.67%
Positive	26 (43.33%)	0 (0.00%)	
Negative	2 (3.33%)	32 (53.33%)	
	Femoral Region		
	Positive	**Negative**	Sensitivity = 95.83% Specificity = 100% PPV = 100% NPV = 97.33% DA = 98.33%
Positive	23 (38.33%)	0 (0.00%)	
Negative	1 (1.67%)	36 (60.00%)	
	Tibial Region		
	Positive	**Negative**	Sensitivity = 96.00% Specificity = 100% PPV = 100% NPV = 97.22% DA = 98.33%
Positive	24 (40.00%)	0 (0.00%)	
Negative	1 (1.67 %)	35 (58.33%)	

DISCUSSION

Peripheral artery disease (PAD), a kind of systemic atherosclerosis, is decrease in blood flow to lower limbs caused by narrowed or blocked blood arteries.[10, 11] Complex and severe pathophysiology of PAD in individuals with diabetes mellitus involves factors including inflammation, medial artery calcification, endothelial dysfunction and persistent hyperglycemia.[2, 12] These mechanisms lead to rapid plaque growth and involvement of several arteries at different levels. As a result, patients often experienced unique clinical symptoms and delay in diagnosis. Importance of early discovery of PAD cannot be overstated. Patients having diabetes attain high risk of limb amputation, slow rate of wound healing and increased infection rates associated with delays in diagnosis. Imaging is essential to diagnose PAD and evaluate its severity. CT angiography shows arterial stenosis and blockages in detail while DUS shows patterns of blood flow throughout body.[2, 13]

This study revealed that DUS and CT angiography are reliable techniques to diagnose and evaluate PAD in diabetics. DUS was performed on 60 patients, showed high sensitivity in aorto-iliac (92.86%), femoral (95.83%) and tibial (96.00%) regions. When compared to CT angiography it keeping it as reference or gold standard, DUS had specificity of 100% in all segments. Overall diagnostic accuracy surpassed 96% across arterial segments, demonstrating that DUS is effective and primarily non-invasive evaluation of PAD in diabetics. Diagnostic characteristics align with current findings, indicated that DUS may serve as main screening tool due to superior sensitivity and specificity in detecting severe artery stenosis in lower extremities. In multicenter cohort, DUS demonstrated strong association with CT angiography in diabetics having PAD, particularly for proximal segments.[14]

This study showed that CT angiography is superior in detection of more severe grades of stenosis and to find distant disease conditions, even though it is comprehensive diagnostic tool. In tibial region, CT angiography showed higher percentage of grade 3 and grade 4 stenosis (18.33% and 8.33%, respectively) than Doppler, showed 13.33% for grade 3. CT angiography makes it easier to figure out what stage of PAD in diabetics and plan therapies since it displays arteries better and has superior spatial resolution. This is especially important because DUS cannot show full extent of disease or might miss distant lesions that are influenced by arterial calcification, common in diabetes. Numerous studies have consistently shown that CT angiography is superior than DUS alone in identifying infrapopliteal lesions and assessing their severity.[5]

Our study found high hypertension rate (78.33%) and poor glycemic control (73.33% with HbA1c ≥7%) in diabetics. Both of them affect systemic risk factors that make PAD worse. These comorbidities are recognized factors that worsen atherosclerosis and result in inferior vascular outcomes. Similar studies in Pakistan regarding PAD patterns and risk factors indicating higher frequency of concurrent hypertension and diabetes in local populations, supporting need for targeted screening in high-risk groups. Descriptive research conducted in Peshawar indicated 58.3% of patients with diabetic foot ulcers presented with PAD. Studies linked poor glycemic control to progression of vascular disease.[15] Another DUS study of lower leg conducted in Karachi. They found luminal width of distal artery varied a lot across patients with diabetes. This means that changes in blood vessels caused by diabetes may not be very noticeable.[16]

Another study showed that DUS was 95.4% sensitive and 76.2% specific when compared to CT angiography. This is a line with our study. Increased sensitivity, but difficulties in distinguishing advanced or complex distal lesions.[7] Results supported conclusion of this study that CT angiography is effective tool for validation and anatomical delineation, especially in revascularization or intervention. DUS still cost-effective and easy-to-use technology. Both modalities yield substantial results. But CT angiography is superior and can affect treatment choices.

There are certain limitations of this study. Small sample size and single-center design may limit generalizability of these results to broader groups. Operator dependency of DUS may introduce bias while application of CT angiography may be constrained by risk of contrast nephropathy in persons with renal impairment. This study did not utilize digital subtraction angiography (DSA) as definitive gold standard, which would provide more precise correlation of stenosis severity than CT angiography alone. Future multicenter investigations, together with the integration of long-term clinical outcomes and cost-effectiveness analysis, would enhance understanding of suitable imaging modalities in diabetic PAD.

CONCLUSION

This study concluded that DUS is a reliable, non-invasive and cost-effective technique for initial screening and evaluation of PAD in diabetic patients, particularly during early and intermediate stages. It has high level of diagnostic accuracy in large artery segments and is useful in common clinical settings. CT angiography is still superior in diagnosing of advanced and distal artery disease, though, because it displays anatomy in great detail. DUS and CT angiography work well together to give both functional and anatomical information. This makes it easier to establish correct diagnoses, learn more about disease and choose best treatment options for PAD in diabetics.

AUTHORS CONTRIBUTIONS:

Author	Contribution
AZ	Majorly Contributed in Study Designing, Analysis and Data Acquisition. Manuscript Writing and Finalized for Submission.
MS	Majorly Contributed in Study Designing, Data Acquisition and Data Interpretation. Has Reviewed, Wrote and Finalized Manuscript for Submission.
AAK	Majorly Contributed in Study Design and Data Analysis. Approved Finalized Version of Manuscript for Submission.
FJL	Majorly Contributed to Data Collection and Analysis. Approved Finalized Version of Manuscript for Submission.
US	Majorly Contributed in Data Analysis and Interpretation. Finally Approved Finalized Version of Manuscript for Submission.
MK	Majorly Contributed in Study Designing and Data Analysis. Approved Finalized Version of Manuscript for Submission.

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