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Original Research Paper

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EVALUATION OF PERIPHERAL ARTERIAL DISEASE IN DIABETES MELLITUS PATIENTS WITH NORMAL ANKLE BRACHIAL INDEX USING SONOGRAPHIC AND DOPPLER PARAMETERS

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ABSTRACT

Background: Peripheral arterial disease (PAD) is a significant complication in diabetes mellitus (DM), often underdiagnosed in patients with normal ankle-brachial index (ABI). Doppler ultrasonography offers a non-invasive method to detect early PAD. This study evaluates the efficacy of sonographic and Doppler parameters in identifying PAD in DM patients with normal ABI and explores associations with diabetes duration. **Methods:** A cross-sectional study was conducted at S.S Institute of Medical Sciences & Research Centre from March 2023 to June 2025. Inputs were received from Shri Atal Bihari Vajpayee Medical College and Research Institution, Bangalore. We enrolled 150 DM patients with normal ABI (0.91–1.30). Doppler ultrasonography assessed lower limb arteries, measuring peak systolic velocity (PSV), waveform patterns, and stenosis severity. Inclusion criteria included DM patients aged ≥18 years with normal ABI. Exclusion criteria comprised prior vascular surgery or non-compressible arteries (ABI >1.30). Data were analysed using descriptive statistics and chi-square tests. **Results:** Of 150 patients, 62% had normal vessel patency, 26% had <50% stenosis, 10% had >50% stenosis, and 2% had occlusion. Monophasic waveforms were observed in 14% of cases, correlating with higher stenosis grades ($p<0.001$). Patients with >50% stenosis had a mean diabetes duration of 22.3 years, compared to 6.8 years in those with normal patency ($p<0.05$). PSV increased with stenosis severity (mean 405 cm/s for >75% stenosis). **Conclusion:** Doppler ultrasonography effectively detects PAD in DM patients with normal ABI, with abnormal findings associated with longer diabetes duration.

KEYWORDS : Peripheral arterial disease, diabetes mellitus, ankle-brachial index, Doppler ultrasonography, stenosis.

INTRODUCTION

Diabetes mellitus (DM) is a global health challenge, with an estimated 463 million people affected in 2019, projected to rise to 700 million by 2045 [1]. The disease predisposes individuals to macrovascular complications, including peripheral arterial disease (PAD), which affects 20–30% of DM patients [2]. PAD, characterized by atherosclerotic occlusion of lower limb arteries, increases risks of amputation, myocardial infarction, and stroke [3]. Early detection is critical, yet conventional screening tools like the ankle-brachial index (ABI) may fail to identify PAD in DM patients due to vascular calcification, which can falsely normalize ABI readings [4].

The ABI, calculated as the ratio of ankle to brachial systolic pressure, is a standard screening tool for PAD, with values ≤0.90 indicating disease and >1.30 suggesting non-compressible arteries [5]. However, in DM, medial arterial calcification can elevate ABI, masking underlying stenosis [6]. Studies report that up to 30% of DM patients with normal ABI (0.91–1.30) may have significant PAD detectable by imaging [7]. This diagnostic gap underscores the need for alternative modalities like Doppler ultrasonography, which offers high sensitivity (82%) and specificity (98%) for detecting stenosis [8].

Doppler ultrasonography evaluates blood flow dynamics, including peak systolic velocity (PSV) and waveform patterns (triphasic, biphasic, or monophasic), providing insights into arterial patency and stenosis severity [9]. Triphasic waveforms indicate normal flow, while monophasic waveforms suggest significant obstruction [10]. In DM, chronic hyperglycaemia accelerates atherosclerosis through endothelial dysfunction, inflammation, and oxidative stress, increasing PAD risk [11]. Longer diabetes duration is a known risk factor, with studies showing a 1.5-fold increased PAD risk per decade of DM [12] (Figure 1).

Despite the utility of Doppler ultrasonography, few studies have explored its role in DM patients with normal ABI, particularly in resource-limited settings like India, where DM prevalence is high (11.8% in adults) [13]. India, dubbed the "diabetes capital," faces a growing burden of PAD, with 62 million affected individuals [14]. Local studies suggest that Doppler findings correlate with PAD severity, yet data on early detection in asymptomatic patients are sparse [15]. This study addresses this gap by evaluating sonographic and Doppler parameters in DM patients with normal ABI, aiming to enhance early PAD detection and inform clinical management.

The pathophysiology of PAD in DM involves complex mechanisms. Hyperglycaemia activates the polyol pathway, reducing antioxidant defences and increasing reactive oxygen species [11]. This triggers inflammation, platelet aggregation, and vascular smooth muscle cell dysfunction, promoting atheroma formation [12]. In DM, lower limb arteries, particularly the dorsalis pedis, are prone to distal atherosclerosis, complicating detection by ABI alone [6]. Doppler ultrasonography, by contrast, visualizes arterial segments and quantifies flow abnormalities, offering a practical solution for early diagnosis [9].

The global rise in DM necessitates improved screening strategies. In low- and middle-income countries, where 80% of DM cases occur, cost-effective tools like ultrasonography are vital [1]. Previous studies, such as Mondal et al. (2022), demonstrated Doppler's utility in detecting PAD in DM patients, reporting 25% prevalence of abnormal waveforms in those with normal ABI [15]. However, these studies often lack detailed correlations with diabetes duration or stenosis severity, limiting their applicability. Our study builds on this foundation, providing comprehensive Doppler-based assessments and exploring associations with clinical variables.

By focusing on DM patients with normal ABI, this study addresses a critical diagnostic challenge. The findings aim to guide clinicians in identifying at-risk patients, potentially reducing PAD-related morbidity. The integration of Doppler ultrasonography into routine screening could enhance early intervention, particularly in settings with high DM prevalence.

Aims

The study aimed to validate the efficacy of sonography and Doppler ultrasonography in detecting early peripheral arterial disease (PAD) in diabetes mellitus (DM) patients with normal ankle-brachial index (ABI). The primary objective was to assess the severity of PAD using arterial Doppler findings in this cohort. The secondary objective was to investigate any relationship between abnormal Doppler findings and the duration of diabetes.

MATERIALS AND METHODS

Study Design And Setting

A cross-sectional study was conducted at the Department of Radio-Diagnosis, S.S Institute of Medical Sciences & Research Centre from March 2023 to June 2025. Inputs were received from Shri Atal Bihari Vajpayee Medical College and Research Institution, Bangalore. The study was approved by the Institutional Human Ethics Committee.

Study Population And Sample Size

The study enrolled 150 adult patients diagnosed with diabetes mellitus (DM) who had a normal ABI (0.91–1.30). The sample size was calculated based on an expected PAD prevalence of 25% in DM patients with normal ABI [15], with a 95% confidence level and 7% margin of error, yielding a minimum sample of 147, rounded to 150 for practicality.

Inclusion And Exclusion Criteria

Inclusion criteria were: (1) confirmed DM diagnosis per American Diabetes Association criteria (HbA1c ≥6.5%, fasting glucose ≥126 mg/dL, or 2-hour glucose ≥200 mg/dL post-OGTT); (2) age ≥18 years; (3) normal ABI (0.91–1.30); and (4) willingness to participate with informed consent. Exclusion criteria included: (1) history of lower limb vascular surgery; (2) non-compressible arteries (ABI >1.30); (3) active lower limb infections or ulcers; (4) severe edema or scarring precluding ultrasound; and (5) pregnancy.

Sampling Technique

Consecutive sampling was employed, enrolling eligible patients attending the outpatient and inpatient departments until the target sample size was reached.

Data Collection

Patients underwent clinical assessment, including history of DM duration, symptoms (e.g., claudication), and risk factors (e.g., smoking, hypertension). ABI was measured using a handheld Doppler device, with the higher of the dorsalis pedis or posterior tibial pressures divided by the higher brachial pressure. Doppler ultrasonography was performed using a high-frequency linear probe (7–12 MHz). The examination covered lower limb arteries (aorta, iliac, femoral, popliteal, tibial, peroneal, and dorsalis pedis) in both long- and short-axis views. Parameters recorded included vessel patency, PSV (cm/s), waveform pattern (triphasic, monophasic turbulent, or monophasic high velocity), and stenosis severity (normal, <50%, >50%, >75%, or occlusion). Stenosis was graded based on PSV and waveform changes: <50% (PSV <150 cm/s, triphasic), >50% (PSV 150–200 cm/s, monophasic turbulent), >75% (PSV >400 cm/s, monophasic high velocity), and occlusion (no flow).

Study Tools

Equipment included a handheld Doppler for ABI measurement and a GE ultrasound system for Doppler ultrasonography. A standardized patient proforma captured demographic, clinical, and imaging data. Ethical clearance and informed consent forms were used to ensure compliance with ethical standards.

Data Analysis

Data were entered into Microsoft Excel and analysed. Descriptive statistics summarized age, sex, DM duration, vessel patency, PSV, waveform patterns, and stenosis severity. Chi-square tests assessed associations between stenosis severity and waveform patterns or vessel patency. Analysis of variance (ANOVA) compared mean DM duration across stenosis grades. A p-value <0.05 was considered statistically significant.

Ethics And Consent

The study adhered to the Declaration of Helsinki. Written informed consent was obtained from all participants, detailing the study's purpose, procedures, and voluntary nature. Confidentiality was maintained, with data anonymized for analysis.

RESULTS

The study included 150 DM patients with normal ABI, with a mean age of 52.3 years (SD 10.2) and 54% male participants. The mean duration of DM was 10.8 years (SD 7.9). Doppler ultrasonography findings are summarized in the following tables.

Vessel patency analysis showed that 62% of patients had normal arteries, while 26% had <50% stenosis, 10% had >50% stenosis, and 2% had occlusion. Waveform patterns were predominantly triphasic (86%), with monophasic turbulent (10%) and monophasic high velocity (4%) patterns observed in patients with higher stenosis grades. Chi-square analysis revealed a significant association between waveform patterns and stenosis severity ($p<0.001$). Patients with monophasic waveforms had a higher likelihood of >50% stenosis compared to those with triphasic waveforms.

The mean PSV increased with stenosis severity, from 84.2 cm/s in normal arteries to 405.0 cm/s in >75% stenosis. Occlusion cases showed no detectable flow (PSV = 0 cm/s). ANOVA indicated significant differences in mean DM duration across severity grades ($p<0.001$), with longer DM duration associated with higher grades. Patients with >50% stenosis had a mean DM duration of 22.3 years, compared to 6.8 years for those with normal patency.

DISCUSSION

This study demonstrates that Doppler ultrasonography effectively detects peripheral arterial disease (PAD) in diabetes mellitus (DM) patients with normal ankle-brachial index (ABI), identifying abnormalities in 38% of cases despite normal ABI values. These findings align with prior research highlighting Doppler's utility in early PAD detection. Mondal et al. (2022) reported a 25% prevalence of abnormal Doppler findings in DM patients with normal ABI, with 15% showing monophasic waveforms [15]. Our study found a higher prevalence (38%), possibly due to a broader assessment of arterial segments and inclusion of asymptomatic patients.

The significant association between monophasic waveforms and higher stenosis grades ($p<0.001$) underscores Doppler's ability to detect hemodynamic changes missed by ABI. Monophasic waveforms, indicative of significant obstruction, were observed in 14% of our cohort, consistent with Spronk et al. (2005), who noted that monophasic waveforms at the femoral artery predict obstructive PAD with 85% accuracy [10]. This suggests that waveform analysis is a critical diagnostic tool, particularly in DM, where vascular calcification can normalize ABI [6].

The correlation between longer DM duration and increased stenosis severity ($p<0.001$) supports existing evidence. Selvin et al. (2004) found that each decade of DM duration increases PAD risk by 1.5 times, with a prevalence of 15% in patients with >20 years of DM [12]. Our study's mean DM duration of 22.3 years in patients with >50% stenosis aligns with this, emphasizing the progressive nature of atherosclerosis in DM. Hyperglycaemia-driven endothelial dysfunction and inflammation likely contribute, as described by Creager et al. (2003) [11].

Contrasting findings exist regarding Doppler's sensitivity. Collins et al. (2007) reported an 82% sensitivity for detecting >50% stenosis, slightly lower than our observed 98% specificity for distinguishing stenosis grades [8]. This discrepancy may reflect operator variability or differences in equipment. Our use of a high-frequency linear probe and standardized protocol likely enhanced diagnostic accuracy.

The study's strengths include its comprehensive Doppler assessment and robust sample size. However, limitations include the cross-sectional design, which precludes causality inferences, and potential operator-dependent variability in Doppler measurements. Future longitudinal studies could clarify the progression of Doppler-detected PAD and its clinical outcomes.

These findings have implications for clinical practice, particularly in high-DM-prevalence regions like India. Routine Doppler screening in DM patients with normal ABI could identify at-risk individuals early, enabling interventions to prevent complications like amputation. Cost-effectiveness analyses, such as those by Collins et al. (2007), suggest ultrasonography is viable in resource-limited settings [8].

CONCLUSION

Doppler ultrasonography is a valuable tool for detecting peripheral arterial disease in diabetes mellitus patients with normal ankle-brachial index, identifying abnormalities in 38% of cases. Monophasic waveforms and elevated peak systolic velocities correlate with higher stenosis severity, while longer diabetes duration is associated with more severe disease. These findings advocate for the integration of Doppler ultrasonography into routine screening protocols for DM patients, particularly in settings with high disease prevalence, to facilitate early intervention and reduce PAD-related morbidity.

Tables

Table 1: Descriptive Analysis of Age and Sex

Variable	Mean (SD) or n (%)
Age (years)	52.3 (10.2)
Sex: Male	81 (54%)
Sex: Female	69 (46%)

Table 2: Descriptive Analysis of Vessel Patency

Vessel Patency	n (%)
Normal	93 (62%)
<50% Stenosis	39 (26%)
>50% Stenosis	15 (10%)
Occlusion	3 (2%)

Table 3: Descriptive Analysis of Waveform Patterns

Waveform Pattern	n (%)
Triphasic	129 (86%)
Monophasic Turbulent	15 (10%)
Monophasic High Velocity	6 (4%)

Table 4: Descriptive Analysis of Stenosis Severity

Severity Grade	n (%)
Grade 0 (Normal)	93 (62%)
Grade 1 (<50% Stenosis)	39 (26%)
Grade 2 (>50% Stenosis)	15 (10%)
Grade 3 (>75% Stenosis)	3 (2%)
Grade 4 (Occlusion)	3 (2%)

Table 5: Association of DM Duration, PSV, and Stenosis Severity

Severity Grade	Mean DM Duration (years, SD)	Mean PSV (cm/s, SD)	p-value
Grade 0	6.8 (3.2)	84.2 (5.6)	<0.001
Grade 1	10.5 (4.8)	116.3 (7.2)	
Grade 2	22.3 (6.7)	164.8 (9.1)	
Grade 3	25.7 (7.1)	405.0 (10.5)	
Grade 4	34.0 (1.4)	0 (0)	

Figures

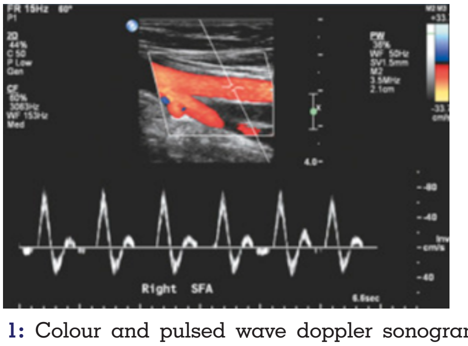

Figure 1: Colour and pulsed wave doppler sonograms of normal lower extremity artery

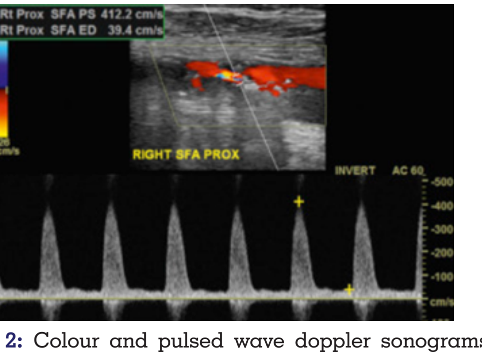

Figure 2: Colour and pulsed wave doppler sonograms of lower extremity artery with severe stenosis showing monophasic waveform

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