ASSESSMENT OF PERIPHERAL VASCULAR DISEASE IN PATIENTS WITH DIABETIC FOOT ULCERS AT A RURAL TERTIARY CARE CENTRE

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Abstract

Background: Diabetic foot ulcers are a major complication of diabetes mellitus and are associated with substantial morbidity, prolonged hospitalization, and an increased risk of lower limb amputation. Peripheral vascular disease (PVD) plays a significant role in impaired wound healing and poor clinical outcomes among these patients. Early vascular assessment is essential for timely diagnosis and management.

Methods: A prospective observational study was conducted in the Department of General Surgery at R. L. Jalappa Hospital and Research Centre, Kolar, Karnataka, India. A total of 250 patients with diabetic foot ulcers were included. Demographic data, duration of diabetes mellitus, smoking history, Wagner grading, Ankle-Brachial Index (ABI), and Doppler ultrasonography findings were recorded. Peripheral vascular disease was diagnosed based on ABI ≤0.9 and/or Doppler evidence of arterial stenosis or occlusion. Statistical analysis was performed using SPSS version 26.0.

Results: The mean age of participants was 56.8 ± 10.4 years, with a male predominance. Peripheral vascular disease was identified in 156 patients (62.4%). Mild PVD was the most common category observed. Doppler ultrasonography demonstrated arterial stenosis in 47.2% and arterial occlusion in 14.4% of patients. ABI findings showed a significant correlation with Doppler findings ($p < 0.001$). Smoking history, longer duration of diabetes mellitus, and higher Wagner grades were significantly associated with the presence of peripheral vascular disease.

Conclusion: Peripheral vascular disease is highly prevalent among patients with diabetic foot ulcers. The Ankle-Brachial Index is a simple, reliable, and cost-effective screening tool that demonstrates good correlation with Doppler ultrasonography findings. Early vascular assessment can facilitate timely intervention, improve limb salvage, and reduce complications, particularly in resource-limited rural healthcare settings.

Keywords: Peripheral vascular disease; Diabetic foot ulcer; Diabetes mellitus; Ankle-Brachial Index; Doppler ultrasonography; Peripheral arterial disease.

1. Introduction

Diabetes mellitus is one of the most prevalent chronic metabolic disorders worldwide and is associated with a wide range of microvascular and macrovascular complications. Among these,

diabetic foot ulcers represent a major cause of morbidity, prolonged hospitalization, reduced quality of life, and lower limb amputations. It is estimated that 15–25% of patients with diabetes will develop a foot ulcer during their lifetime, making diabetic foot disease a significant healthcare challenge [1].

The pathogenesis of diabetic foot ulcers is multifactorial and involves peripheral neuropathy, infection, and peripheral vascular disease (PVD). Peripheral vascular disease, also known as peripheral arterial disease, results from progressive atherosclerotic narrowing of the lower extremity arteries, leading to reduced tissue perfusion and impaired wound healing. In patients with diabetes mellitus, chronic hyperglycemia accelerates endothelial dysfunction and atherosclerosis, increasing the risk of vascular insufficiency and its associated complications [2].

Peripheral vascular disease significantly contributes to delayed ulcer healing, recurrent infections, gangrene, and an increased risk of lower limb amputation in diabetic patients. Early detection of vascular impairment is therefore essential for appropriate management and improved clinical outcomes. Several diagnostic methods are available for the assessment of peripheral vascular disease, among which the Ankle-Brachial Index (ABI) is considered a simple, non-invasive, reliable, and cost-effective screening tool. Doppler ultrasonography further aids in evaluating arterial blood flow and identifying the site and severity of arterial stenosis or occlusion [5,6].

Previous studies have demonstrated a high prevalence of peripheral vascular disease among patients with diabetic foot ulcers and have emphasized the importance of routine vascular assessment. Prompers et al. reported a high burden of ischemia and infection among diabetic foot patients in Europe, while Jude et al. found that diabetic patients with peripheral arterial disease experienced more severe lower limb involvement and poorer outcomes compared with non-diabetic patients [3,4]. ABI has been shown to correlate well with Doppler ultrasonography findings and is widely recommended for the diagnosis and evaluation of peripheral arterial disease [5,6]. Early vascular assessment facilitates timely intervention, improves wound healing, enhances limb salvage rates, and reduces disease-related complications [7].

Patients presenting to rural tertiary care centers often experience delayed diagnosis and limited access to specialized vascular services, which may contribute to advanced disease at presentation and poorer outcomes. Despite the clinical importance of peripheral vascular disease in diabetic foot ulcer patients, data from rural healthcare settings remain limited. Therefore, the present study was undertaken to assess peripheral vascular disease in patients with diabetic foot ulcers using Ankle-Brachial Index and Doppler ultrasonography at a rural tertiary care center and to evaluate the association of peripheral vascular disease with demographic and clinical risk factors.

2. Materials and Methods

This prospective observational study was conducted in the Department of General Surgery, R. L. Jalappa Hospital and Research Centre, Sri Devaraj Urs Academy of Higher Education and Research (SDUAHER), Kolar, Karnataka, India, from May 2025 to March 2026 after obtaining approval from the Central Ethics Committee of Sri Devaraj Urs Academy of Higher Education and Research prior to commencement of the study. Written informed consent was obtained from all participants before enrollment in the study.

A total of 250 patients diagnosed with diabetic foot ulcers were included in the study. Patients aged 30 years and above with diagnosed diabetes mellitus presenting with diabetic foot ulcers to the Department of General Surgery during the study period were eligible for inclusion. Patients with non-diabetic foot ulcers, previous lower limb revascularization procedures, major lower limb amputation, acute limb ischemia secondary to trauma or embolism, and those unwilling to provide informed consent were excluded from the study.

The sample size was calculated using the formula for estimation of a single proportion, considering an expected prevalence of peripheral vascular disease of 60%, a 95% confidence interval, and an allowable error of 10%. The minimum calculated sample size was 93 patients. To improve the precision of estimates and enhance the reliability of subgroup analysis, a total of 250 patients were included in the study.

Demographic and clinical details including age, gender, duration of diabetes mellitus, smoking history, and ulcer characteristics were recorded using a structured proforma. Ulcer severity was assessed using the Wagner Classification System [8]. Peripheral vascular disease was evaluated in all patients using the Ankle-Brachial Index (ABI) and Doppler ultrasonography. ABI measurement was performed using a handheld Doppler device and sphygmomanometer under standardized conditions. Patients were placed in the supine position and allowed to rest for approximately 10 minutes before measurement. Systolic blood pressure was measured in both brachial arteries, and the higher reading was considered as the reference brachial pressure. At the ankle, systolic pressure was measured over the dorsalis pedis artery and posterior tibial artery using a handheld Doppler probe. The higher ankle pressure was used for ABI calculation according to the formula:

ABI = Ankle Systolic Pressure / Higher Brachial Systolic Pressure [6].

ABI values greater than 0.90 were considered normal, values between 0.70 and 0.90 were suggestive of mild peripheral vascular disease, values between 0.40 and 0.69 indicated moderate disease, and values less than 0.40 were considered indicative of severe ischemia [6,7]. Peripheral vascular disease was defined as ABI $\leq$0.90 with supportive Doppler ultrasonography findings suggestive of arterial stenosis or occlusion.

Doppler ultrasonography of the lower limb arteries was performed in all patients to assess arterial blood flow characteristics and identify the presence, location, and severity of arterial stenosis or occlusion. All patient information was recorded confidentially and used solely for research purposes.

Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Associations between categorical variables were analyzed using the Chi-square test or Fisher's exact test wherever appropriate. Correlation between ABI findings and Doppler ultrasonography findings was assessed using appropriate statistical methods. A p-value of less than 0.05 was considered statistically significant.

3. Results and Discussion

A total of 250 patients with diabetic foot ulcers were included in the study. The mean age of the study population was 56.8 ± 10.4 years. Male patients constituted the majority of the study population, accounting for 178 (71.2%) cases, while females accounted for 72 (28.8%) cases. The mean duration of diabetes mellitus was 8.6 ± 4.2 years, and 132 (52.8%) patients had a history of smoking. The baseline demographic characteristics of the study population are presented in Table 1.

Table 1. Baseline Demographic Characteristics of the Study Population

Variable	Findings (n=250)
Mean age (years)	56.8 ± 10.4
Male/Female	178/72
Mean duration of diabetes (years)	8.6 ± 4.2
Smoking history present	132 (52.8%)

The majority of patients had diabetes mellitus for more than five years. Patients with diabetes duration of 5–10 years and greater than 10 years each accounted for 41.6% of the study population. The distribution of diabetes duration is shown in Table 2.

Table 2. Distribution of Duration of Diabetes Mellitus

Duration of Diabetes	Frequency (n)	Percentage (%)
<5 years	42	16.8
5–10 years	104	41.6
>10 years	104	41.6

Ulcer severity was assessed using the Wagner Classification System. Wagner grades 2 and 3 were the most commonly observed ulcer grades, accounting for 34.4% and 36.8% of cases respectively. The distribution of Wagner grades is shown in Table 3.

Table 3. Wagner Classification of Diabetic Foot Ulcers

Wagner Grade	Frequency (n)	Percentage (%)
Grade 1	34	13.6
Grade 2	86	34.4
Grade 3	92	36.8
Grade 4	30	12.0
Grade 5	8	3.2

Peripheral vascular disease was assessed using Ankle-Brachial Index (ABI) and Doppler ultrasonography. A total of 156 patients (62.4%) demonstrated ABI values ≤0.9 suggestive of peripheral vascular disease. Mild peripheral vascular disease was the most commonly observed category. The distribution of ABI findings is presented in Table 4.

Table 4. Distribution of Ankle-Brachial Index Values

ABI Category	Frequency (n)	Percentage (%)
Normal (>0.9)	94	37.6
Mild PVD (0.7–0.9)	78	31.2
Moderate PVD (0.4–0.7)	54	21.6
Severe Ischemia (<0.4)	24	9.6

Doppler ultrasonography demonstrated arterial stenosis or occlusion in the majority of patients with abnormal ABI findings. Arterial stenosis was the most common abnormality observed, followed by arterial occlusion. The Doppler ultrasonography findings are summarized in Table 5.

Table 5. Doppler Ultrasonography Findings

Doppler Finding	Frequency (n)	Percentage (%)
Normal arterial flow	96	38.4
Arterial stenosis	118	47.2
Arterial occlusion	36	14.4

A statistically significant correlation was observed between ABI findings and Doppler ultrasonography findings ($\chi^2 = 198.4$, $p < 0.001$). Among patients with ABI ≤0.9, 150 demonstrated abnormal Doppler findings, whereas only four patients with normal ABI showed Doppler abnormalities. These findings indicate good diagnostic agreement between ABI and Doppler ultrasonography in the assessment of peripheral vascular disease (Table 6).

Table 6. Correlation Between ABI and Doppler Findings

ABI Finding	Abnormal Doppler	Normal Doppler	Total
ABI ≤0.9	150	6	156
ABI >0.9	4	90	94

Smoking history demonstrated a significant association with peripheral vascular disease. Peripheral vascular disease was present in 102 of 132 smokers compared with 54 of 118 non-smokers ($\chi^2 = 26.7$, $p < 0.001$), indicating a strong relationship between smoking and vascular insufficiency in diabetic foot ulcer patients (Table 7).

Table 7. Association Between Smoking History and Peripheral Vascular Disease

Smoking History	PVD Present	PVD Absent	Total
Present	102	30	132
Absent	54	64	118

Peripheral vascular disease was also significantly associated with longer duration of diabetes mellitus. Patients with diabetes duration greater than 10 years demonstrated the highest prevalence of peripheral vascular disease ($\chi^2 = 24.5$, $p < 0.001$). The association between duration of diabetes mellitus and peripheral vascular disease is shown in Table 8.

Table 8. Association Between Duration of Diabetes Mellitus and Peripheral Vascular Disease

Duration of Diabetes	PVD Present	PVD Absent	Total
<5 years	14	28	42
5–10 years	62	42	104
>10 years	80	24	104

Higher Wagner grades demonstrated a significant association with peripheral vascular disease ($\chi^2 = 18.9$, $p = 0.002$). Patients with advanced ulcer grades showed increased prevalence of vascular insufficiency, emphasizing the role of ischemia in the progression of diabetic foot disease (Table 9).

Table 9. Association Between Wagner Grade and Peripheral Vascular Disease

Wagner Grade	PVD Present	PVD Absent	Total
Grade 1	12	22	34
Grade 2	46	40	86
Grade 3	70	22	92
Grade 4	22	8	30
Grade 5	6	2	8

The present study demonstrated a high prevalence of peripheral vascular disease (62.4%) among patients with diabetic foot ulcers. This finding is comparable with previous studies by Prompers et al. [3] and Jude et al. [4], who reported a high burden of ischemia and peripheral arterial disease among diabetic foot patients. The high prevalence observed in the present study highlights the importance of routine vascular assessment in diabetic foot ulcer patients, particularly in rural healthcare settings where delayed presentation is common.

An important finding of the present study was the strong correlation between ABI and Doppler ultrasonography findings. ABI demonstrated good diagnostic agreement with Doppler evaluation, supporting previous observations by Fowkes et al. [5] and Aboyans et al. [6], who emphasized the value of ABI as a simple and reliable screening tool for peripheral arterial disease. Given its non-invasive nature, low cost, and ease of application, ABI can be effectively utilized in resource-limited settings for early detection of vascular insufficiency.

Smoking history and longer duration of diabetes mellitus were significantly associated with peripheral vascular disease in the present study. These findings are consistent with the observations of Beckman et al. [2], who described the role of endothelial dysfunction and accelerated atherosclerosis in the development of peripheral arterial disease among diabetic patients. Chronic hyperglycemia and tobacco exposure contribute to progressive vascular injury, thereby increasing the risk of ischemic complications and delayed wound healing.

The study also demonstrated a significant association between higher Wagner grades and peripheral vascular disease. Patients with advanced ulcer grades exhibited a greater frequency of vascular insufficiency, suggesting that ischemia plays a critical role in ulcer progression and poor healing outcomes. Similar observations have been reported by Wagner [8] and Apelqvist et al. [9], who highlighted the prognostic importance of vascular assessment in diabetic foot disease.

Although the present study provides valuable insights into the burden of peripheral vascular disease among diabetic foot ulcer patients, it was limited by its single-center design and lack of long-term follow-up. Advanced vascular imaging modalities such as CT angiography were not routinely performed. Larger multicentric studies with long-term follow-up are therefore warranted to further evaluate vascular outcomes, ulcer healing, and limb salvage rates in diabetic foot patients.

4. Conclusion

Peripheral vascular disease is highly prevalent among patients with diabetic foot ulcers and represents a major contributor to delayed wound healing and adverse clinical outcomes. The present study demonstrated that 62.4% of patients with diabetic foot ulcers had evidence of peripheral vascular disease, highlighting the substantial burden of vascular insufficiency in this population. Significant associations were observed between peripheral vascular disease and smoking history, longer duration of diabetes mellitus, and higher Wagner ulcer grades.

Ankle-Brachial Index (ABI) showed good correlation with Doppler ultrasonography findings and proved to be a simple, reliable, non-invasive, and cost-effective tool for the assessment of peripheral vascular disease. Routine vascular evaluation using ABI, supplemented by Doppler ultrasonography when indicated, can facilitate early diagnosis and timely intervention in patients with diabetic foot ulcers.

Early identification and management of vascular insufficiency may improve wound healing, enhance limb salvage, and reduce disease-related complications, particularly in rural healthcare settings where access to specialized vascular services may be limited. Further multicentric studies with larger sample sizes and long-term follow-up are recommended to evaluate the impact of peripheral vascular disease on ulcer healing, amputation rates, and long-term patient outcomes.

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Competing Interest

The authors declare no competing interests.

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