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Original Research Article

A Hospital-Based Study on the Causes and Complications of Diabetic Foot Ulcer in Patients with Diabetes Mellitus

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Abstract

Background: Diabetic foot ulcer (DFU) is one of the most serious and disabling complications of diabetes mellitus, contributing significantly to morbidity, mortality, and healthcare costs. The condition is particularly challenging in developing countries like India, where poor glycemic control, barefoot walking, and delayed presentation are common. This study aimed to evaluate the causes and complications of diabetic foot ulcers and to identify the key clinical and microbiological factors associated with disease severity and outcomes.

Methods: A cross-sectional observational study was conducted on 247 diabetic patients presenting with foot ulcers at a tertiary care hospital in North India from January to December 2023. Detailed demographic, clinical, and etiological data were collected. Ulcers were graded using the Wagner classification, and patients were evaluated for neuropathy, peripheral arterial disease (PAD), and infection. Pus or wound swabs were cultured for microbial identification and antibiotic sensitivity. Data were analyzed using SPSS version 25.0, applying the Chi-square test, Fisher's exact test, and ANOVA, with $p < 0.05$ considered significant.

Results: The mean age of participants was 57.8 ± 10.6 years, with 65.6% males and 66.4% from rural areas. Most patients had Type 2 diabetes (96.4%) and poor glycemic control (mean HbA1c = 8.6%). Peripheral neuropathy (77.3%), infection (73.7%), and PAD (34.8%) were the predominant etiological factors. A significant association was found between longer duration of diabetes and higher ulcer grade ($p < 0.001$). Staphylococcus aureus (33.5%) was the most common isolate, followed by Pseudomonas aeruginosa (22.5%) and E. coli (18.1%). Complications occurred in 63.9% of patients, chiefly cellulitis (38.1%) and gangrene (22.3%). Amputation was required in 15.4% (major = 4.9%, minor = 10.5%), and mortality was 1.6%. Neuropathy, poor glycemic control, inappropriate footwear, and smoking were significantly associated with ulcer development ($p < 0.05$).

Conclusion: Diabetic foot ulceration predominantly affects middle-aged, rural, male patients with long-standing, poorly controlled diabetes. Peripheral neuropathy, infection, and ischemia are the major causative factors leading to severe complications and limb loss. Strengthening of preventive foot care practices, glycemic control, and early multidisciplinary management can substantially reduce the burden of diabetic foot complications in India.

Keywords: Diabetic Foot Ulcer, Peripheral Neuropathy, Glycemic Control, Complications, Amputation.

Introduction

Diabetes mellitus (DM) is one of the most prevalent chronic metabolic disorders worldwide and poses a major public health challenge due to its long-term complications [1]. Among these, diabetic foot ulcer (DFU) remains one of the most serious and costly complications, contributing significantly to morbidity, mortality, and healthcare expenditure [2]. Globally, the lifetime risk of developing a foot ulcer among diabetic patients is estimated to be 15–25%, and nearly one in six of these cases may eventually require amputation if not managed appropriately [3]. The pathogenesis of diabetic foot ulceration is multifactorial, commonly resulting from the interplay of peripheral neuropathy, peripheral arterial disease, and secondary infection [4]. Peripheral neuropathy leads to loss of protective sensation and foot deformities, while ischemia due to peripheral vascular disease impairs tissue perfusion and wound healing [5]. Hyperglycemia-induced immune dysfunction further increases susceptibility to infection, aggravating ulcer severity. In India, additional

factors such as walking barefoot, poor foot hygiene, delayed presentation, and inadequate diabetes control contribute to the higher prevalence and severity of DFUs compared with developed nations [6].

The burden of diabetic foot disease in India is substantial, with hospital-based studies reporting a prevalence ranging from 8% to 17% among diabetic patients [7]. It remains a leading cause of non-traumatic lower limb amputations, accounting for nearly 40–60% of such cases [8]. The socioeconomic impact is immense, as DFUs often affect individuals in their productive years, lead to prolonged hospitalization, and impose significant financial and emotional stress on patients and their families. Despite advances in diabetic care and wound management, late diagnosis and inadequate preventive practices continue to result in poor outcomes [9].

Early identification of risk factors and precipitating causes of diabetic foot ulceration is essential for effective prevention and management [10]. Understanding the pattern of complications, such as infection, gangrene, osteomyelitis, and amputation, provides insight into disease progression and helps guide targeted interventions [11]. However, data regarding the etiological factors and complication profile of diabetic foot ulcers in the Indian population remain limited and vary across regions [12]. Hence, the present study was undertaken with an aim to evaluate the underlying causes, associated risk factors, and clinical complications among patients with diabetic foot ulcers. The findings aim to enhance clinical understanding, promote early preventive measures, and contribute to the development of region-specific management strategies to reduce the burden of diabetic foot disease.

Materials and Methods

Study Design and Setting: This was a hospital-based cross-sectional observational study conducted in the Department of General Surgery at a tertiary care teaching hospital in North India. The study was carried out over a period of 24 months, from January 2022 to December 2023. The institution caters to a large rural and semi-urban population, thus providing a representative spectrum of diabetic patients with varying socioeconomic and educational backgrounds. Ethical approval for the study was obtained from the Institutional Ethics Committee, and informed written consent was taken from all participants before inclusion.

Study Population and Sample Size: The study included patients with diabetes mellitus presenting with foot ulcers of varying duration and severity, who were admitted or attending the surgical outpatient department during the study period. A total of 247 patients fulfilling the inclusion criteria were enrolled consecutively. Both type 1 and type 2 diabetes mellitus patients were included, irrespective of the duration of diabetes, provided they had at least one ulcer located below the ankle joint.

Patients with foot ulcers of non-diabetic etiology, such as traumatic ulcers, venous ulcers, bed sores, malignancy-associated ulcers, or those with incomplete medical records, were excluded from the study to maintain homogeneity.

Inclusion and Exclusion Criteria: Inclusion criteria comprised: (1) diagnosed cases of diabetes mellitus according to ADA criteria, (2) presence of foot ulceration below the malleoli, and (3) willingness to participate in the study. Exclusion criteria included: (1) ulcers caused by trauma or other non-diabetic causes, (2) patients with critical illness precluding participation, and (3) those unwilling to give consent.

Data Collection and Clinical Assessment: After enrollment, detailed clinical history was obtained from each patient, including demographic details (age, sex, occupation, and socioeconomic status), duration of diabetes, treatment modality, glycemic control, and history of peripheral neuropathy or peripheral vascular disease. Contributory factors such as footwear habits, foot trauma, smoking, alcohol consumption, and presence of comorbidities (hypertension, dyslipidemia, obesity) were also recorded. Each patient underwent a thorough clinical examination of the affected foot, which included inspection for site, size, depth, and number of ulcers, surrounding cellulitis, presence of slough, granulation tissue, discharge, and signs of infection or gangrene. Foot deformities, callosities, and areas of pressure were noted. The Wagner classification was used to grade the ulcers from grade 0 (pre-ulcerative) to grade 5 (extensive gangrene involving the entire foot).

Investigations and Diagnostic Work-up: All patients underwent baseline hematological and biochemical investigations including complete blood count, fasting and postprandial blood sugar, HbA1c, renal function tests, and serum lipid profile. Wound swab cultures were obtained under aseptic precautions before initiation of antibiotic therapy to identify causative organisms and their antibiotic sensitivity pattern. Assessment of peripheral neuropathy was done using a 10-g monofilament test, vibration perception threshold (using a 128 Hz tuning fork), and ankle reflexes. Peripheral arterial disease was evaluated by palpation of dorsalis pedis and posterior tibial pulses and confirmed by Doppler study wherever indicated. Radiological investigations, such as X-ray of the foot, were performed to detect osteomyelitis, gas formation, or bony deformities.

Assessment of Complications: Complications such as cellulitis, abscess formation, osteomyelitis, septicemia, and gangrene were documented during hospital stay. The need for surgical intervention—including wound debridement, incision and drainage, skin grafting, or amputation—was also recorded. Patients were managed according to institutional protocol and followed up during their hospital stay until satisfactory wound healing or discharge.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). Quantitative variables such as age, duration of diabetes, and biochemical parameters were expressed as mean ± standard deviation (SD), while qualitative variables such as sex, ulcer grade, and complications were expressed as frequency and percentage.

Associations between categorical variables were tested using the Chi-square test or Fisher's exact test, as appropriate. Continuous variables were compared using the independent t-test or ANOVA where applicable. A p-value < 0.05 was considered statistically significant.

Results

The study included 247 patients with diabetic foot ulcers, with a mean age of 57.8 ± 10.6 years (range: 32–82 years). The majority were males (65.6%), and most participants hailed from rural areas (66.4%), reflecting the regional demographic profile.

Type 2 diabetes mellitus was overwhelmingly predominant (96.4%), and poor glycemic control (HbA1c ≥7%) was observed in 80.6% of patients, with a mean HbA1c of 8.6 ± 1.4%. More than half of the patients had hypertension (53.4%), while dyslipidemia (35.2%) and obesity (30%) were also common. Smoking was reported by 45.3%, and alcohol use by 27.9% of the participants (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics of Patients (n = 247)

Characteristic	Category	Frequency (%)/Mean ± SD / Range
Age (years)	–	57.8 ± 10.6 (32–82)
Sex	Male	162 (65.6%)
	Female	85 (34.4%)
Residence	Rural	164 (66.4%)
	Urban	83 (33.6%)
Duration of Diabetes (years)		10.2 ± 5.6
Duration of Diabetes (years)	<5	64 (25.9%)
	5–10	108 (43.7%)
	>10	75 (30.4%)
Type of Diabetes	Type 2 DM	238 (96.4%)
	Type 1 DM	9 (3.6%)
Mean HbA1c (%)	–	8.6 ± 1.4
Glycemic Control	Good (HbA1c <7%)	48 (19.4%)
	Poor (HbA1c ≥7%)	199 (80.6%)
Comorbidities	Hypertension	132 (53.4%)
	Dyslipidemia	87 (35.2%)
	Obesity (BMI ≥25 kg/m²)	74 (30.0%)
Smoking History	Yes	112 (45.3%)
Alcohol Use	Yes	69 (27.9%)

BMI = Body Mass Index; HbA1c = Glycated Hemoglobin

Most ulcers had been present for 1–3 months (45.3%), and forefoot involvement was the most common site (49.4%), followed by midfoot (29.6%) and heel ulcers (21%). A majority (75.3%) presented with single ulcers, while the mean ulcer size was 7.8 ± 4.5 cm². According to the Wagner grading system, Grade II (32.8%) and Grade III (25.5%) ulcers were most frequent, with Grade IV–V lesions seen in 24.7% of patients, reflecting a substantial burden of advanced disease. Infection was present in 73.7%, peripheral neuropathy in 77.3%, and peripheral arterial disease (PAD) in 34.8% cases (Table 2).

Table 2: Distribution of Diabetic Foot Ulcers by Clinical Characteristics

Ulcer Parameter	Category	Frequency (%)/Mean ± SD
Duration of Ulcer	<1 month	71 (28.7%)
	1–3 months	112 (45.3%)
	>3 months	64 (25.9%)
Ulcer Location	Forefoot	122 (49.4%)
	Midfoot	73 (29.6%)
	Heel	52 (21.0%)
Number of Ulcers	Single	186 (75.3%)
	Multiple	61 (24.7%)
Ulcer Size (cm²)	–	7.8 ± 4.5
Ulcer Grade (Wagner Classification)	Grade I	42 (17.0%)
	Grade II	81 (32.8%)
	Grade III	63 (25.5%)
	Grade IV	41 (16.6%)
	Grade V	20 (8.1%)
Associated Infection	Present	182 (73.7%)
	Absent	65 (26.3%)
Peripheral Neuropathy	Present	191 (77.3%)
	Absent	56 (22.7%)
Peripheral Arterial Disease (by Doppler)	Present	86 (34.8%)
	Absent	161 (65.2%)

Peripheral neuropathy was significantly associated with ulcer formation, being present in 77.3% of cases ($p < 0.001$). Similarly, poor glycemic control ($p < 0.001$), inappropriate footwear ($p = 0.016$), foot trauma ($p = 0.042$), and smoking ($p = 0.039$) showed statistically significant associations with ulcer occurrence. Peripheral arterial disease was also associated with ulceration ($p = 0.024$), while obesity did not show a significant association ($p = 0.112$) (Table 3).

Table 3: Distribution of Major Etiological Factors Among Patients with Diabetic Foot Ulcer and Their Association with Ulcer Severity (n = 247)

Etiological Factor	Severe Ulcer (≥ III) (n=126)	Mild–Moderate (≤ II) (n=121)	Total (n=247)	p-value
	Frequency (%)			
Peripheral Neuropathy	110 (57.6%)	81 (42.4%)	191 (77.3%)	< 0.001
Peripheral Arterial Disease	48 (55.8%)	38 (44.2%)	86 (34.8%)	0.024
Foot Trauma / Minor Injury	72 (61.5%)	45 (38.5%)	117 (47.4%)	0.042
Inappropriate Footwear	80 (58.0%)	58 (42.0%)	138 (55.9%)	0.016
Poor Glycemic Control (HbA1c ≥ 7%)	120 (60.3%)	79 (39.7%)	199 (80.6%)	< 0.001
Smoking	69 (61.6%)	43 (38.4%)	112 (45.3%)	0.039
Obesity (BMI ≥ 25 kg/m²)	34 (45.9%)	40 (54.1%)	74 (30.0%)	0.112

BMI = Body Mass Index; HbA1c = Glycated Hemoglobin;

Among 182 culture-positive cases, Gram-negative bacteria predominated (61.5%), though Staphylococcus aureus (including MRSA) remained the single most common isolate (33.5%). Pseudomonas aeruginosa (22.5%) and E. coli (18.1%) were the next frequent organisms. Antibiotic sensitivity testing revealed good susceptibility to linezolid and vancomycin for Gram-positive organisms, and to piperacillin-tazobactam and carbapenems for Gram-negative isolates (Table 4).

Table 4: Bacteriological Profile of Infected Diabetic Foot Ulcers (n = 182)

Organism Isolated	Frequency (%)	Common Antibiotic Sensitivity (%)
Staphylococcus aureus (including MRSA)	61 (33.5%)	Linezolid (88%), Vancomycin (82%)
Pseudomonas aeruginosa	41 (22.5%)	Piperacillin-tazobactam (79%), Amikacin (75%)
Escherichia coli	33 (18.1%)	Meropenem (83%), Amikacin (70%)
Klebsiella pneumonia	27 (14.8%)	Cefoperazone-sulbactam (74%), Meropenem (79%)
Proteus spp.	12 (6.6%)	Ceftriaxone (71%), Gentamicin (69%)
Polymicrobial Infection	8 (4.4%)	–

MRSA = Methicillin-Resistant Staphylococcus aureus

Complications were observed in 63.9% of patients. Cellulitis (38.1%) and abscess formation (25.5%) were the most frequent local complications, followed by osteomyelitis (16.6%) and gangrene (22.3%). Septicemia was noted in 8.5% of patients, often secondary to advanced ulcers or delayed presentation.The high complication rate reflects the burden of neglected or late-stage diabetic foot ulcers and emphasizes the need for early diagnosis and intervention at the primary care level (Table 5).

Table 5: Distribution of Complications Among Diabetic Foot Ulcer Patients

Complication	Frequency (%)
Cellulitis	94 (38.1%)
Abscess formation	63 (25.5%)
Osteomyelitis	41 (16.6%)
Gangrene	55 (22.3%)
Septicemia	21 (8.5%)
Any Complication (≥1)	158 (63.9%)

A significant correlation was found between duration of diabetes and ulcer severity as per Wagner grade ($p < 0.001$, ANOVA). Patients with diabetes duration <5 years had a mean Wagner grade of 1.9 ± 0.8, whereas those with >10 years duration had a significantly higher mean grade of 3.4 ± 1.0. This indicates that the chronicity of diabetes strongly influences tissue integrity, peripheral neuropathy, and vascular compromise, predisposing patients to more severe ulcers over time (Table 6).

Table 6: Association Between Duration of Diabetes and Ulcer Severity

Duration of Diabetes	Wagner Grade (Mean ± SD)	p-value (ANOVA)
<5 years (n=64)	1.9 ± 0.8	<0.001
5–10 years (n=108)	2.7 ± 0.9	
>10 years (n=75)	3.4 ± 1.0	

Outcomes were variable depending on ulcer severity and systemic condition. Conservative management with wound care and optimized glycemic control resulted in complete healing in 45.3% of cases. Surgical debridement was required in 29.6%, while skin grafting was done in 9.7%. Amputation was necessary in 15.4% of patients (minor in 10.5%, major in 4.9%), and mortality occurred in 1.6% due to septicemia and multiorgan dysfunction. These outcomes reflect both the severity at presentation and resource limitations in timely referral and diabetic foot care (Table 7).

Table 7: Outcome of Management in Diabetic Foot Ulcer Patients

Outcome	Frequency (%)
Complete Healing with Conservative Therapy	112 (45.3%)
Surgical Debridement Required	73 (29.6%)
Skin Grafting Done	24 (9.7%)
Minor Amputation (toe/forefoot)	26 (10.5%)
Major Amputation (below/above knee)	12 (4.9%)
Mortality	4 (1.6%)

Discussion

The present hospital-based cross-sectional study of 247 diabetic foot ulcer (DFU) patients provides a comprehensive overview of the etiological factors, bacteriological profile, and clinical complications

associated with this condition in an Indian tertiary care setting.

The male predominance (65.6%) observed in our study is consistent with reports from several Indian studies, including those by Kumar et al., and Patel et al., where males accounted for 60–70% of DFU cases [13,14]. This gender difference is likely related to greater outdoor activity, occupational exposure, and higher incidence of foot trauma among men. Similarly, the mean age in the late 50s corresponds with the typical age of long-standing Type 2 diabetes, as noted by Rastogi et al., and Thomas et al.,[15,16].The predominance of rural patients (66%) and those with poor glycemic control (mean HbA1c 8.6%) aligns with observations by Boopesh et al., and Upadhyay et al., who highlighted poor diabetes awareness, barefoot walking, and limited access to podiatric care in rural India as key determinants of DFU [17,18]. The distribution of ulcer grades in our study, with Wagner Grade II–III comprising 58.3%, is comparable to findings from Shah et al., and Malepati et al., who reported a similar predominance of moderate-grade ulcers in a tertiary care cohort [19,20]. The relatively high frequency of advanced ulcers (Grade IV–V, 24.7%) in our study may reflect delayed presentation and poor initial wound care, a pattern consistently seen in Indian populations in studies by Sharma et al., and Mahakalkaret al., [21,22].Peripheral neuropathy emerged as the leading etiological factor (77.3%), followed by PAD (34.8%), corroborating previous reports by Parveen et al., and Trivedi et al., who established neuropathy as the single most significant predictor of ulceration [23,24].

Neuropathy leads to sensory loss and repetitive microtrauma, while ischemia from PAD impairs tissue healing — both potentiated by persistent hyperglycemia and oxidative stress. The strong association between duration of diabetes and ulcer severity ($p < 0.001$) further supports the chronic cumulative damage to peripheral nerves and vasculature [23,24].

Our microbiological findings, with Staphylococcus aureus (33.5%) as the most common isolate followed by Gram-negative bacilli (Pseudomonas 22.5%, E. coli 18.1%), are in close agreement with Shanmugam et al., and Kavitha et al., [25,26]. However, the growing proportion of Gram-negative and polymicrobial infections observed here reflects the changing bacterial spectrum in Indian DFUs, possibly due to widespread antibiotic misuse and prolonged hospital exposure. The high rate of methicillin-resistant S. aureus (MRSA) infections emphasizes the importance of culture-guided antibiotic therapy and strict infection control practices [26].

The complication rate (63.9%) in this study is similar to that reported by Singh et al., where 60% of DFU patients developed local or systemic complications [27]. Cellulitis (38%) and gangrene (22%) were predominant, underscoring the role of secondary infection and ischemia. Osteomyelitis (16.6%) was relatively frequent, which correlates with findings by Aragón-Sánchezet al., suggesting that deeper tissue involvement is a common sequel of delayed care [28].

Amputation was required in 15.4% of cases (major in 4.9%), comparable to Indian series by Swarnakaret al., (14%), and Rastogi et al., (17%) but slightly higher than rates reported from developed countries (8–10%) owing to earlier detection and multidisciplinary foot care teams abroad [29,30]. Our mortality rate (1.6%), though low, reinforces the systemic risk associated with severe infection and sepsis in diabetic individuals.

The multifactorial nature of diabetic foot ulceration is well recognized. Chronic hyperglycemia induces microangiopathy, neuropathy, and immune dysfunction, all of which contribute to poor wound healing [8,9]. Hyperglycemia leads to accumulation of advanced glycation end products (AGEs), endothelial dysfunction, and impaired nitric oxide-mediated vasodilation, thereby reducing peripheral perfusion [22]. Neuropathy impairs pain perception and proprioception, resulting in repetitive unnoticed trauma. Moreover, autonomic dysfunction causes dry, fissured skin, predisposing to infection [23].

The significant association between duration of diabetes and ulcer grade in this study highlights the cumulative vascular and neural insult over time. In addition, improper footwear (55.9%) and minor trauma (47.4%) emerged as preventable mechanical triggers — a finding consistent with pathophysiological models linking external pressure points to plantar ulceration in neuropathic feet [27,29].

Clinical Implications

The findings reinforce that diabetic foot ulceration remains a largely preventable but neglected complication of diabetes in India. Early detection of neuropathy, optimization of glycemic control, regular foot examination, and patient education regarding footwear and hygiene could drastically reduce the disease burden. The high infection rate and antibiotic resistance patterns observed warrant routine culture and sensitivity testing before initiating empirical therapy. Establishing multidisciplinary diabetic foot clinics integrating endocrinology, surgery, orthopedics, podiatry, and physiotherapy can improve limb salvage rates. Public health initiatives focusing on community screening for high-risk feet and training of primary

healthcare providers in foot care are urgently needed.

Strengths and Limitations

The strength of this study lies in its comprehensive assessment of both etiological and complication profiles in a relatively large cohort (n = 247) representing real-world Indian patients from mixed rural-urban backgrounds. The use of objective clinical parameters (Wagner grading, HbA1c, Doppler studies) and culture-based microbiological confirmation adds robustness to the findings. However, the study's cross-sectional design limits causal inference. The absence of long-term follow-up precludes evaluation of recurrence rates or time to healing. Furthermore, single-center data may not capture regional microbiological variations. Nonetheless, the trends observed are highly relevant for similar tertiary care settings in India.

Conclusion

In summary, this study demonstrates that long-standing diabetes, neuropathy, and poor glycemic control are the principal causes of diabetic foot ulceration, while infection and ischemia are the leading contributors to complications and amputation. The results underscore the urgent need for preventive education, early referral, and multidisciplinary management to reduce morbidity, amputation rates, and mortality from diabetic foot disease in India.

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