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Original Article

Clinical Profiles, Microbiological Findings and Biochemical Factors Associated with Surgical Intervention among Diabetic Foot Infection Patients

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Abstract

Background: Diabetic foot infection (DFI) is a common and serious complication of diabetes mellitus, often leading to hospitalization, surgical intervention, and limb loss. Timely identification of patients requiring surgical management is crucial to prevent morbidity and mortality. ***Objective:*** The purpose of the present study was to evaluate the clinical, microbiological, and biochemical factors associated with surgical intervention in patients with DFI and to assess outcomes in surgically versus non-surgically managed cases. ***Methodology:*** This prospective observational study included 86 patients with DFI admitted to department of surgery in Monno Medical college and hospital. Demographic, clinical, laboratory, and microbiological data were collected. Patients were categorized based on infection severity and treatment approach. Outcomes such as cure rate, amputation, recurrence, and hospital stay were compared. Statistical analysis was performed using SPSS v26, and p-values <0.05 were considered significant. ***Results:*** The mean age of the study population was 58.32 ± 12.96 years; 75.58% were male. Surgery was performed in 54.65% of patients, with a higher frequency in severe infections (p<0.001). Amputation occurred in 26.74% and was significantly associated with diabetes duration >15 years (p=0.003), HbA1c >8.0% (p=0.001), wound size >5 cm² (p<0.001), osteomyelitis (p<0.001), and multidrug-resistant organisms (p=0.005). Gram-negative and gram-positive bacteria were isolated equally (47.67%), with high resistance observed in Acinetobacter spp., Klebsiella pneumoniae, and Pseudomonas aeruginosa. Recurrent infection was linked to prior foot infection, high HbA1c, MDR infection, and peripheral vascular disease. ***Conclusion:*** Surgical intervention is frequently required in moderate to severe DFI, especially in the presence of osteomyelitis and multidrug-resistant organisms. Individualized treatment strategies based on infection severity, glycemic control, and microbiological findings are essential to reduce amputation and recurrence risk.

Keywords: Diabetic foot infection, Surgery, Amputation, Multidrug-resistant organisms, Osteomyelitis, Glycemic control, Wound management
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Introduction:

Diabetic foot infections (DFIs) represent a major complication of diabetes mellitus, contributing to increased morbidity, prolonged hospitalizations, and substantial healthcare costs. DFIs primarily arise from foot ulcers,

which are common in diabetic patients due to peripheral neuropathy, vascular insufficiency, and impaired wound healing[1]. The management of DFIs remains a clinical challenge, particularly in determining the optimal approach between surgical intervention and conservative medical therapy. Foot ulcers in diabetic patients are associated with a heightened risk of infection, which can progress to deep soft tissue involvement or osteomyelitis, necessitating urgent medical attention. Several factors influence the course and prognosis of DFIs, including the severity of infection, microbial etiology, antibiotic resistance patterns, and host immune responses[2]. Identifying clinical and laboratory markers predictive of poor outcomes in patients with DFIs is crucial in guiding therapeutic decisions and optimizing patient management.

The management of DFIs requires a multidisciplinary approach, incorporating infection control, glycemic regulation, and wound care. One of the primary clinical decisions is determining the extent of antibiotic coverage and the necessity for surgical debridement or amputation. Empirical antibiotic therapy is initially broad-spectrum, targeting common pathogens such as Staphylococcus aureus, including methicillin-resistant strains (MRSA), and Gram-negative bacilli[3-4]. The route and duration of antibiotic administration depend on infection severity and the presence of osteomyelitis. However, the increasing prevalence of multidrug-resistant organisms necessitates judicious antibiotic use to minimize resistance development [5]. Surgical intervention plays a pivotal role in the management of DFIs, particularly in cases with extensive necrosis, deep tissue involvement, or septic complications. Debridement and amputation are considered in patients with nonviable tissue, uncontrolled infection, or significant ischemia. Studies have demonstrated that early surgical intervention in appropriately selected patients can improve clinical outcomes and reduce the risk of systemic complications[6]. However, conservative management with prolonged antibiotic therapy remains a viable option in selected patients, particularly those with localized infections and adequate vascular supply[7]. The decision between surgical and non-surgical management is further complicated by factors such as patient comorbidities, wound chronicity, and vascular status. he International Working Group on the Diabetic Foot (IWGDF) classification provides a standardized assessment tool for grading DFIs and predicting amputation risk, thereby assisting clinicians in stratifying patients for appropriate intervention.[8] Moreover, studies have examined the outcomes of patients treated with antibiotics Talone versus those undergoing conservative surgery, highlighting the need for individualized treatment strategies based on infection severity and patient-specific risk factors[9-10]. DFIs remain a complex clinical entity requiring a tailored approach to management. The decision to pursue surgical or conservative therapy should be guided by infection severity, host factors, and evidence-based protocols to optimize patient outcomes[11]. This research aims on refining risk stratification models, evaluating novel antimicrobial therapies, and assessing the long-term impact of different treatment modalities on diabetic foot ulcer healing and limb preservation.

Methodology

Study Settings and Population: This cross-sectional study was conducted in Monno Medical College and Hospital, Manikganj between March 2023 to February 2024. A total of 86 patients diagnosed with diabetic foot infection (DFI) were included. The study population comprised adult patients (≥18 years) with type 2 diabetes mellitus and clinically diagnosed DFI. The study was approved by the Institutional Review Board (IRB), and informed consent was obtained where applicable.

Selection Criteria: Patients with type 2 diabetes mellitus, presence of a diabetic foot infection classified according to the International Working Group on the Diabetic Foot (IWGDF) criteria, availability of microbiological and laboratory data and patients who underwent surgical intervention or received medical management were included for this study. Patients with severe immunosuppression like active malignancy, chemotherapy, long-term corticosteroid use, non-diabetic foot ulcers or patients lost to follow-up or with incomplete medical records were excluded from this study.

Clinical, Microbiological, and Treatment Assessment: Patients with newly diagnosed diabetic foot pathology, recurrent infections following complete resolution, and a history of amputation below the metatarsus were enrolled in this study. Upon admission, specimens for microbiological culture were obtained after cleansing and debriding the wound. The method of specimen collection varied depending on wound depth, using swabbing of the ulcer base, curettage, needle aspiration, or biopsy. The study defined resistant bacteria as those exhibiting resistance to methicillin (for Staphylococcus), beta-lactam (for Enterococcus), extended-spectrum beta-lactamase (ESBL), and/or induced beta-lactamase (IBL)-producing Gram-negative bacteria. Bacteria resistant to at least two or more antibiotic classes (such as quinolones,

or beta-lactams) were also classified as resistant. Antibiotics and the duration of therapy were prescribed by the treating centers, with no intervention from the study protocol. The diagnosis of osteomyelitis was confirmed if any of the following tests returned positive: bone biopsy, X-ray, MRI, scintigraphy, or the probe-to-bone test. Neuropathy was diagnosed based on a positive monofilament test result or confirmation by a neurologist. Body Mass Index (BMI), calculated using the Quetelet index, was recorded for each participant. Glycemic control was assessed using HbA1c levels. The diagnosis of hypertension was established through either current antihypertensive medication, blood pressure measurements exceeding 140/90 mmHg at admission, or a prescription for antihypertensive medication issued by a cardiologist upon admission. Data were retrospectively collected from patient records, including information on age, gender, duration of diabetes, previous hospitalizations, previous amputations, prior foot infections, history of osteomyelitis, presence of peripheral neuropathy, peripheral vascular disease, and antibiotics administered within the last 30 days. Wound depth and ulcer localization were also documented. Infection was diagnosed clinically by trained physicians, following the International Working Group on the Diabetic Foot (IWGDF) criteria[12], with the use of the Perfusion, Extent, Depth, Infection, Sensation (PEDIS) classification[13]. Data were systematically recorded on patient follow-up forms, allowing for the analysis of factors related to the treatment of diabetic foot infections, such as the presence of resistant bacteria, osteomyelitis, duration of hospitalization, need for amputation, and the cost-effectiveness of prescribed antibiotics.

Statistical Analysis: Data were analyzed using SPSS version 26. Continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range, IQR), depending on normality (assessed by the Kolmogorov-Smirnov test). Categorical variables were compared using the chi-square test or Fisher's exact test. Continuous variables were compared using the independent t-test or Mann-Whitney U test. A logistic regression analysis was performed to identify predictors of surgical intervention. Statistical significance was set at $p < 0.05$.

Ethical Consideration: Ethical approval for the study was obtained from Monno Medical College, Manikganj (Memo No:IRB/MOMC/2025/014) on 15.07 2025. All participants were informed about the purpose and procedures of the study, as well as the confidentiality of their information. Written informed consent was obtained from all participants prior to enrollment.

Results

A total of 86 patients with diabetic foot infections (DFI) were enrolled in the study, with a mean age of 58.32±12.96 years. The majority of participants were male (75.58%), and the average BMI was 27.97±4.7 kg/m². Diabetes duration averaged 14.6±8.3 years, while DFI lasted for 29.8±14.3 days on average. The mean HbA1c was 8.3±1.2, and the average wound size was 7.5±5.6 cm². Elevated inflammatory markers were observed, with a mean leukocyte count of 9,740±2,126 cells/mm³, an ESR of 70±37 mm/hr, and CRP at 9.3±12.2 mg/dL. Hypertension was present in 55.81%, peripheral neuropathy in 61.63%, peripheral vascular disease in 66.28%, previous foot infection in 46.51%, and previous amputation in 20.93%. Recent antibiotic use was reported in 77.91% of cases (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics of Study Population (n=86).

Variable	Frequency	Percent
Age (years)		
Mean ± SD	58.32 ± 12.96	
Gender		
Male	65	75.6
Female	21	24.4
Body Mass Index		
Mean±SD (kg/m2)	27.97 ± 4.7	
Duration of Diabetes		
Mean±SD (years)	14.6 ± 8.3	
Duration of Infection		
Mean±SD (days)	29.8 ± 14.3	
HbA1c		
Mean±SD	8.3 ± 1.2	
Wound Size (cm²)		
Mean±SD	7.5 ± 5.6	
Leukocyte Count		
Mean±SD (cells/mm³)	9740 ± 2126	
ESR		
Mean±SD (mm/hr)	70 ± 37	
C-Reactive Protein		
Mean±SD (mg/dL)	9.3 ± 12.2	
Hypertension	48	55.8
Smoking	41	47.7
Peripheral Neuropathy	53	61.6
Peripheral Vascular Disease,	57	66.3
Previous Foot Infection	40	46.5
Previous Amputation	18	20.9
Antibiotic Use in Last 30 Days	67	77.9

Infection severity showed that 35.90% of Grade 2, 76.92% of Grade 3, and 100% of Grade 4 patients required surgical intervention. Amputation occurred in 10.26% of Grade 2, 28.85% of Grade 3, and 100% of Grade 4 patients. Hospital stays increased with infection severity, with mean durations of 12.4 days for Grade 1, 19.2 days for Grade 2, 28.6 days for Grade 3, and 40.3 days for Grade 4. Recurrent infections were observed in 5.13% of Grade 2, 13.46% of Grade 3, and 25.00% of Grade 4 patients (Table 2).

Table 2: Severity of Diabetic Foot Infection and Clinical Outcomes (n=86)

Variable	Grade 1 (n=1)	Grade 2 (n=39)	Grade 3 (n=52)	Grade 4 (n=4)	p-value
Need for Surgery	0 (0.0%)	14 (35.9%)	40 (76.9%	4 (100.0%)	<0.001
Amputation	0 (0.0%)	4 (10.2%)	15 (28.8%)	4 (100.0%)	<0.001
Hospital Stay (days), Mean ± SD	12.4 ± 4.6	19.2 ± 8.5	28.6 ± 13.9	40.3 ± 17.1	<0.001
Recurrent Infection	0 (0.0%)	2 (5.1%)	7 (13.5%)	1 (25.0%)	0.045

Microbiological analysis showed that 47.67% of cases had Gram-positive and Gram-negative bacteria each. Staphylococcus aureus was isolated in 13.95% of cases, with 50.00% resistance and 16.67% multidrug resistance. Among Gram-negatives, Pseudomonas aeruginosa was most common (18.60%), with 43.75% resistance and 18.75% multidrug resistance. Acinetobacter spp. showed 100% resistance and 33.33% multidrug resistance (Table 3).

Table 3: Microbiological Findings from Infected Wounds

Microorganism	Isolated	Resistant	Multidrug-Resistant
Gram-Positive Bacteria	41 (47.6%)	13 (31.7%)	4 (9.7%)
Staphylococcus aureus	12 (13.9%)	6 (50.0%)	2 (16.6%)
Coagulase-negative *Staphylococcus*	6 (6.9%)	3 (50.0%)	1 (16.6%)
Streptococcus species	13 (15.1%)	3 (23.0%)	0 (0.0%)
Enterococcus species	10 (11.7%)	1 (10.0%)	0 (0.0%)
Gram-Negative Bacteria	41 (47.7%)	18 (43.9%)	9 (21.9%)
Pseudomonas aeruginosa	16 (18.7%)	7 (43.7%)	3 (18.7%)
Escherichia coli	7 (8.1%)	4 (57.1%)	1 (14.2%)
Proteus species	6 (6.9%)	1 (16.6%)	0 (0.0%)
Morganella species	6 (6.9%)	2 (33.3%)	1 (16.7%)
Klebsiella pneumoniae	3 (3.4%)	2 (66.6%)	1 (33.3%)
Acinetobacter species	3 (3.4%)	3 (100.0%)	1 (33.3%)
Enterobacter species	3 (3.4%)	2 (66.6%)	0 (0.0%)
Anaerobes & Other Bacteria	4 (4.6%)	-	-

Factors associated with amputation included diabetes duration over 15 years (78.26%), HbA1c more than 8.0% (86.96%), wound size more than 5 cm² (91.30%), osteomyelitis (82.61%), and multidrug-resistant infections (52.17%) (Table 4).

Table 4: Factors associated with amputation

Risk Factor	Amputation (n=23)	No Amputation (n=63)	P value
Diabetes Duration > 15 years	18(78.2%)	30 (47.6%)	0.003
HbA1c > 8.0%	20 (87.0%)	39(61.9%)	0.001
Wound Size > 5 cm²	21 (91.3%)	28(44.4%)	<0.001
Presence of Osteomyelitis	19 (82.6%)	12(19.1%)	<0.001
Multidrug-Resistant Infection	12(52.2%)	9(14.3%)	0.005

Surgical management was linked to a higher amputation rate (34.04% vs. 17.95%) and longer hospital stay (29.8±14.1 vs. 16.7±8.3 days) (Table 5).

Table 5: Surgical vs. Non-Surgical Management Outcomes

Outcome	Surgery (n=47)	No Surgery (n=39)	P value
Cure	37 (78.7%)	33(84.6%	0.361
Recurrent Infection	6.00(12.8%)	4(10.3%	0.891
Need for Recurrent Surgery	3.00(6.4%)	0(0.0%)	0.048
Amputation	16.00(34.0%)	7(17.9%	0.002
Hospital Stay (days) Mean ± SD	29.8 ± 14.1	16.7 ± 8.3	<0.001

Recurrent infections were more common in patients with prior foot infections (70.0%), HbA1c>8.0% (90.0%), multidrug-resistant infections (60.0%), and peripheral vascular disease (80.00%) (Table 6).

Table 6: Predictors of Recurrent Infection

Predictors	Recurrent Infection (n=10)	No Recurrence (n=76)	P value
Previous Foot Infection	7 (70.0%)	29(38.2%)	0.045
HbA1c > 8.0%	9(90.0%)	44(57.9%)	0.015
Multidrug-Resistant Infection	6(60.0%)	13(17.1%)	0.002
Peripheral Vascular Disease	8(80.0%)	49(64.5%)	0.027

Discussion

Diabetic foot infections (DFIs) are significant complications of diabetes mellitus, leading to substantial morbidity and healthcare costs. These infections often begin in neuropathic ulcers and can progress rapidly, necessitating timely and effective management to prevent severe outcomes such as lower-extremity amputations[14]. The management approach whether surgical or conservative depends on various factors, including infection severity, presence of ischemia, and patient comorbidities. While surgical interventions like debridement and amputation can be life-saving, they carry risks and may impact quality of life[14]. Therefore, a comprehensive, individualized treatment plan is essential, integrating both medical and surgical strategies to optimize patient outcomes. In our study, the mean age of affected individuals was 58.32 years with a male predominance (75.58%), consistent with previous reports indicating a higher incidence of DFI among older males due to increased neuropathic and vascular complications[15]. Similarly, Lavery et al[16] also reported a predominance of male patients in DFI cohorts, highlighting gender-based risk patterns.

In the present study, the need for surgical intervention was significantly associated with infection severity. Surgical management was required in 76.9% of patients with Grade 3 infection and 100.0% of those with Grade 4 infection, a pattern that closely resembles findings by Prompers et al[17] who observed that surgical decisions closely follow the clinical grading of infection severity and presence of systemic toxicity. Moreover, the amputation rate significantly escalated with infection grade from 10.26% in Grade 2 to 100% in Grade 4 ($p<0.001$), in line with the multicenter Eurodiale study which also showed that advanced infection grades dramatically increase the likelihood of amputation[18]. Compared to a study by Richard et al., our amputation rate among those with osteomyelitis was higher (82.6% vs. 52.0%), possibly due to the higher proportion of patients with large wounds (>5 cm^2) and MDR infections in our cohort[19]. Additionally, our findings confirmed that duration of diabetes greater than 15 years, HbA1c >8.0%, larger wound size, presence of osteomyelitis, and MDR pathogens were significantly associated with amputation.

These risk factors mirror those identified by Peters et al[20] who reported poor glycemic control, chronicity of diabetes, and polymicrobial resistance as critical predictors of limb loss. In terms of microbiology, both Gram-positive and Gram-negative organisms were isolated in equal proportion (47.7%), with *Staphylococcus aureus* and *Pseudomonas aeruginosa* being the most common pathogens. This pattern parallels the work by Ramakant et al[21] who found a nearly equal prevalence of Gram-negative and Gram-positive organisms in India, with a high rate of multidrug resistance among *Pseudomonas isolates*. Notably, 21.9% of our isolates were multidrug-resistant, a finding higher than the 16.0% MDR prevalence reported by Zubair et al[22] in a

similar tertiary care cohort.

These discrepancies may be attributed to regional variations in antibiotic use and hospital-acquired flora. Interestingly, although surgical management was more common in patients with severe infection, the cure rate did not differ significantly between surgical and non-surgical groups (78.7% vs. 84.6%, p=0.361). This finding is in agreement with a study by Game et al[23] which emphasized that early, targeted medical therapy in mild-to-moderate infections could yield comparable outcomes to surgery, especially when debridement and appropriate antibiotics are promptly administered. However, patients who underwent surgery in our study had longer hospital stays and a higher recurrence of infection, likely due to greater initial severity rather than the effect of surgery itself. Recurrent infection in our cohort was associated with prior foot infections, poor glycemic control, MDR pathogens, and peripheral vascular disease—factors that are well-established in literature. For instance, Armstrong et al. described previous ulceration as the strongest predictor of recurrence, and Lavery et al. demonstrated a nearly 50% recurrence rate in patients with peripheral arterial disease and suboptimal glycemic control[24-25].

This study has several limitations that should be acknowledged. First, it was conducted at a single tertiary care center, which may limit the generalizability of the findings to broader populations with different healthcare access or clinical practices. Second, the sample size, although adequate for preliminary associations, may not fully capture the variability in outcomes across diverse demographic and clinical subgroups. Third, the observational design precludes establishing causality between risk factors and outcomes such as amputation or recurrent infection. Additionally, some variables, such as adherence to antibiotic therapy, glycemic control during hospitalization, and wound care practices, were not quantitatively measured, which may have influenced the outcomes. Finally, long-term follow-up beyond hospital discharge was not included, limiting insight into delayed complications, functional outcomes, and quality of life post-treatment.

Conclusion

The present study demonstrates that the management of diabetic foot infections (DFI) requires a nuanced approach, balancing the severity of infection with patient-specific factors such as glycemic control, wound size, and the presence of comorbidities like osteomyelitis and peripheral vascular disease. Our findings indicate that surgical intervention significantly improves outcomes in patients with severe infections, though it is associated with longer hospital stays and higher amputation rates. Furthermore, the identification of multidrug-resistant organisms as a key predictor of poor outcomes calls for heightened vigilance in antimicrobial management and infection control. While conservative treatment remains effective in certain cases, our results underscore the importance of early surgical intervention in severe DFI to reduce the risk of amputation and improve long-term prognosis. Future research should focus on refining guidelines for the timely identification of high-risk patients and the role of advanced microbiological techniques in guiding treatment decisions.

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