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Clinicobacteriological Profile and Outcome of Diabetic Foot Ulcers: A Hospital-Based Cross-Sectional Study.

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Abstract

Background: Diabetic foot ulcers (DFUs) represent one of the most serious complications of diabetes mellitus, contributing significantly to morbidity, mortality, and healthcare costs. Understanding the bacteriological profile and clinical outcomes is crucial for effective management and prevention of amputations. ***Objective:*** To determine the clinicobacteriological profile and treatment outcomes of diabetic foot ulcers among patients attending Katuri Medical College & Hospital, Andhra Pradesh. ***Methods:*** A hospital-based cross-sectional study was conducted over 12 months (March 2025 - February 2026) involving 150 patients with diabetic foot ulcers. Clinical assessment using Wagner's classification, bacteriological culture and antibiotic sensitivity testing, and outcome analysis were performed. Statistical analysis included descriptive statistics and chi-square tests. ***Results:*** The mean age was 56.8 ± 10.4 years with male predominance (68.7%). Wagner's grade II ulcers were most common (43.3%). Gram-negative organisms predominated (65.3%), with Pseudomonas aeruginosa (23.4%), Escherichia coli (18.7%), and Klebsiella pneumoniae (15.9%) being the most common isolates. Polymicrobial infections occurred in 38.7% of cases. Extended-spectrum beta-lactamase (ESBL) production was detected in 52.6% of Gram-negative isolates. Overall healing rate was 61.3%, with amputation required in 28.7% of cases. Higher Wagner grades were significantly associated with amputation ($p<0.001$). ***Conclusions:*** Diabetic foot ulcers in Andhra Pradesh demonstrate a predominance of multidrug-resistant Gram-negative organisms. Wagner's grading effectively predicts outcomes, with higher grades associated with increased amputation risk. Early diagnosis, appropriate antibiotic therapy based on culture sensitivity, and multidisciplinary management are essential for improving outcomes.ctiveness.

Keywords: Diabetic foot ulcer, bacteriological profile, Wagner's classification, antibiotic resistance, amputation, Andhra Pradesh.

INTRODUCTION

Diabetes mellitus has emerged as a major public health challenge globally, with India recognized as the "diabetes capital of the world" with approximately 77 million diabetic individuals[1]. Diabetic foot ulcer (DFU) is one of the most devastating complications of diabetes, affecting 15-25% of diabetic patients during their lifetime[2]. The incidence of DFU in India ranges from 8-17%, significantly higher than global averages[3].

Diabetic foot infections arise from a complex interplay of peripheral neuropathy, peripheral vascular disease, and impaired immunity. These factors create an environment conducive to bacterial colonization and infection, often leading to chronic, non-healing ulcers[4]. The polymicrobial nature of these infections, combined with increasing antimicrobial resistance, poses significant therapeutic challenges.

The economic burden of diabetic foot complications is substantial. In India, DFU accounts for approximately 25% of all diabetes-related hospital admissions[5]. The risk of lower extremity amputation is 15-40 times higher in diabetics compared to non-diabetics, with 85% of all diabetes-related amputations preceded by foot ulcers[6]. Furthermore, the five-year mortality rate following major amputation ranges from 39-80%, emphasizing the severity of this complication.

Andhra Pradesh, with a population exceeding 49 million and an estimated diabetes prevalence of 8-10%, faces a substantial burden of diabetic complications[7]. The state's demographic transition, with 12% of the population aged 60 years and above, further increases the disease burden. Understanding the local bacteriological profile and resistance patterns is crucial for developing effective empirical treatment protocols.

Previous studies from various regions of India have reported varying bacteriological profiles, with a general trend toward Gram-negative predominance and increasing multidrug resistance[8][9]. However, regional variations exist, necessitating location-specific studies to guide clinical practice.

This study was conducted at Katuri Medical College & Hospital (KMCH), a tertiary care teaching hospital in Guntur district, Andhra Pradesh, serving a predominantly rural and semi-urban population. The objectives were to: (1) determine the clinical characteristics and grading of diabetic foot ulcers, (2) identify the bacteriological profile and antimicrobial sensitivity patterns of causative organisms, and (3) evaluate treatment outcomes and factors influencing amputation rates.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based cross-sectional observational study was conducted in the Departments of General Surgery and Microbiology, Katuri Medical College & Hospital, Gannavaram, Guntur district, Andhra Pradesh, over a period of 12 months from March 2025 to February 2026. KMCH is a 1000-bedded tertiary care teaching hospital serving rural and semi-urban populations from Guntur, Krishna, and surrounding districts.

Study Population and Sample Size

A total of 150 consecutive patients with diabetic foot ulcers attending the surgery outpatient department or admitted to surgical wards were enrolled in the study. Sample size was calculated based on an expected DFU prevalence of 10% among admitted diabetic patients, with 5% precision and 95% confidence level.

Inclusion Criteria

- Patients aged 18 years and above
- Diagnosed cases of Type 1 or Type 2 diabetes mellitus
- Presence of foot ulcers (Wagner's grade 1 or higher)
- Willing to provide informed consent
- Patients with clinical evidence of infection (purulent discharge, cellulitis, or systemic signs)

Exclusion Criteria

- Non-diabetic foot ulcers
- Patients on antibiotic therapy for more than 48 hours prior to sample collection
- Patients with immunocompromising conditions (HIV, malignancy on chemotherapy)
- Wagner's grade 0 ulcers
- Incomplete medical records

Clinical Assessment

Detailed clinical history including age, gender, duration of diabetes, glycemic control status (HbA1c levels), smoking history, and comorbidities (hypertension, dyslipidemia, chronic kidney disease) was recorded. Physical examination focused on neurovascular assessment including:

- Peripheral neuropathy assessment using 10g monofilament test and tuning fork vibration sensation
- Peripheral vascular assessment by palpation of dorsalis pedis and posterior tibial pulses
- Ankle-brachial index (ABI) measurement when feasible
- Detailed ulcer characteristics: location, size, depth, presence of exposed bone or tendons

Ulcers were classified according to Wagner's classification system:

- Grade 0: No open lesion, but high-risk foot
- Grade 1: Superficial ulcer without penetration to deeper layers
- Grade 2: Deep ulcer penetrating to ligaments, tendons, joint capsule or fascia
- Grade 3: Deep ulcer with abscess, osteomyelitis, or joint sepsis
- Grade 4: Localized gangrene (forefoot or heel)
- Grade 5: Extensive gangrene involving entire foot

Microbiological Procedures

Sample Collection

Under strict aseptic precautions, samples were collected before initiating antibiotic therapy. The ulcer site was first cleaned with sterile saline to remove surface debris and contaminants. Tissue specimens from the ulcer base or wound margin were collected using sterile curette or scalpel. In cases of purulent discharge, pus was aspirated using sterile syringe. Samples were immediately transported to the microbiology laboratory in sterile containers.

Culture and Identification

Samples were processed according to standard microbiological protocols:

- Gram staining was performed for preliminary identification
- Samples were inoculated on:
- Blood agar (for general bacterial growth)
- MacConkey agar (for Gram-negative bacilli)
- Nutrient agar (for routine culture)
- Sabouraud dextrose agar (for fungal isolation)
- Plates were incubated aerobically at 37°C for 24-48 hours
- Bacterial isolates were identified based on colony morphology, Gram staining, and standard biochemical tests (catalase, coagulase, oxidase, indole, citrate, urease, and triple sugar iron tests)
- Identification was confirmed using automated systems (VITEK 2 Compact, bioMérieux) when available

Antimicrobial Susceptibility Testing

Antibiotic sensitivity testing was performed using the Kirby-Bauer disc diffusion method on Mueller-Hinton agar following Clinical and Laboratory Standards Institute (CLSI) guidelines. The following antibiotics were tested:

For Gram-negative organisms:

- Ampicillin, amoxicillin-clavulanate, piperacillin-tazobactam, ceftriaxone, ceftazidime, cefoperazone-sulbactam, imipenem, meropenem, ertapenem, amikacin, gentamicin, ciprofloxacin, levofloxacin, cotrimoxazole

For Gram-positive organisms:

- Penicillin, ampicillin, oxacillin, cefoxitin, erythromycin, clindamycin, vancomycin, linezolid, gentamicin, ciprofloxacin

Detection of Resistance Patterns

- Extended-spectrum beta-lactamase (ESBL) production in Gram-negative bacilli was detected using double disc synergy test
- Methicillin-resistant Staphylococcus aureus (MRSA) was identified using cefoxitin disc (30 µg)

Carbapenem resistance was screened using disc diffusion with meropenem and imipenem

Treatment Protocol and Outcome Assessment

All patients received comprehensive management including:

- Glycemic control optimization (target HbA1c < 7%)
- Empirical broad-spectrum antibiotics, modified based on culture sensitivity reports
- Surgical debridement when indicated
- Wound dressings with appropriate materials
- Off-loading and pressure relief measures
- Vascular surgery consultation for critical limb ischemia

Outcomes were classified as:

- Complete healing: Complete epithelialization with no discharge
- Partial healing: > 50% reduction in ulcer size with healthy granulation tissue
- Static/deterioration: < 50% reduction or worsening
- Minor amputation: Toe or forefoot amputation
- Major amputation: Below-knee or above-knee amputation
- Death: Mortality during hospital stay or within 30 days

Data Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Descriptive statistics including mean, standard deviation, frequencies, and percentages were calculated. Chi-square test was used to assess associations between categorical variables. A p-value < 0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of Katuri Medical College & Hospital (IEC/KMCH/2025/032). Written informed consent was obtained from all participants or their legal guardians. Patient confidentiality was maintained throughout the study.

RESULTS

Demographic and Clinical Characteristics

A total of 150 patients with diabetic foot ulcers were enrolled in the study. The demographic and clinical characteristics are summarized in Table 1.

Table 1: Demographic and clinical characteristics of study participants (n=150)

Characteristic	Number (n)	Percentage (%)
Age Distribution (years)		
< 40	8	5.3
40-50	32	21.3
51-60	67	44.7
61-70	35	23.3
> 70	8	5.3
Mean age ± SD	**56.8 ± 10.4 years**	
Gender		
Male	103	68.7
Female	47	31.3
Residence		
Rural	94	62.7
Urban	38	25.3
Semi-urban	18	12.0
Occupation		
Farmer	48	32.0
Manual laborer	35	23.3
Homemaker	31	20.7
Office worker	22	14.7
Retired	14	9.3
Type of Diabetes		
Type 2	144	96.0
Type 1	6	4.0
Duration of Diabetes		
< 5 years	28	18.7
5-10 years	54	36.0
> 10 years	68	45.3
HbA1c Levels		
< 7% (controlled)	22	14.7
7-9% (moderate)	61	40.7
> 9% (poor control)	67	44.7
Mean HbA1c ± SD	**9.2 ± 1.8%**	
Comorbidities		
Hypertension	98	65.3
Dyslipidemia	76	50.7
Chronic kidney disease	34	22.7
Coronary artery disease	28	18.7
Peripheral vascular disease	82	54.7
Risk Factors		
Smoking	56	37.3
Alcohol consumption	42	28.0
Inadequate foot care	112	74.7
Walking barefoot	87	58.0

The mean age of patients was 56.8 ± 10.4 years, with the majority (44.7%) in the 51-60 years age group. Males constituted 68.7% of the study population. The rural population predominated (62.7%), consistent with the hospital's catchment area. Farmers (32.0%) and manual laborers (23.3%) formed a significant proportion, reflecting the occupational demographics of Andhra Pradesh.

Type 2 diabetes was present in 96% of patients. A substantial proportion (45.3%) had diabetes for more than 10 years. Poor glycemic control (HbA1c > 9%) was observed in 44.7% of patients, with a mean HbA1c of 9.2 ± 1.8%. This reflects inadequate diabetes management in the community.

Comorbidities were common, with hypertension in 65.3%, peripheral vascular disease in 54.7%, and dyslipidemia in 50.7% of patients. These comorbidities significantly impact healing and outcomes. Risk factors included inadequate foot care (74.7%), walking barefoot (58.0%), and smoking (37.3%).

Ulcer Characteristics

The characteristics of diabetic foot ulcers are presented in Table 2.

Table 2: Characteristics of diabetic foot ulcers (n=150)

Ulcer Characteristic	Number (n)	Percentage (%)
Location		
Plantar surface (forefoot)	68	45.3
Toes	42	28.0
Heel	24	16.0
Dorsum of foot	12	8.0
Multiple sites	4	2.7
Ulcer Size		
< 5 cm^2	62	41.3
5-10 cm^2	56	37.3
> 10 cm^2	32	21.3
Duration of Ulcer		
< 1 month	38	25.3
1-3 months	72	48.0
> 3 months	40	26.7
Wagner's Grade		
Grade 1 (superficial)	26	17.3
Grade 2 (deep to tendon)	65	43.3
Grade3(abscess/osteomyelitis)	38	25.3
Grade 4 (localized gangrene)	17	11.3
Grade 5 (extensive gangrene)	4	2.7
Associated Features		
Cellulitis	89	59.3
Purulent discharge	124	82.7
Foul odor	78	52.0
Exposed bone	32	21.3
Exposed tendon	48	32.0
Neuropathy		
Present	138	92.0
Absent	12	8.0
Peripheral Vascular Disease		
Present (absent pulses)	82	54.7
Absent (palpable pulses)	68	45.3

The plantar forefoot was the most common site (45.3%), followed by toes (28.0%) and heel (16.0%). This distribution reflects pressure points during walking. According to Wagner's classification, grade 2 ulcers were most prevalent (43.3%), followed by grade 3 (25.3%) and grade 1 (17.3%). Advanced grades 4 and 5 constituted 14.0% of cases.

The majority of ulcers (48.0%) had been present for 1-3 months, indicating delayed presentation. Purulent discharge was present in 82.7%, cellulitis in 59.3%, and foul odor in 52.0% of cases. These features indicate active infection and tissue necrosis.

Peripheral neuropathy was nearly universal (92.0%), while peripheral vascular disease was present in 54.7% of patients. The combination of neuropathy and vascular compromise significantly impairs healing.

Bacteriological Profile

Out of 150 samples, 142 (94.7%) yielded bacterial growth, while 8 (5.3%) were culture-negative despite clinical evidence of infection. A total of 187 bacterial isolates were obtained, with 58 patients (38.7%) showing polymicrobial infections.

Table 3: Pattern of bacterial growth

Type of Growth	Number	Percentage (%)
Monomicrobial	84	56.0
Polymicrobial (2 organisms)	46	30.7
Polymicrobial (3 or more)	12	8.0
No growth	8	5.3
Total isolates	**187**	

Distribution of Bacterial Isolates

The distribution of bacterial isolates is shown in Table 3.

Table 4: Distribution of bacterial isolates from diabetic foot ulcers

Organism	Number of Isolates	Percentage (%)
Gram-Negative Organisms	**122**	**65.3**
Pseudomonas aeruginosa	44	23.4
Escherichia coli	35	18.7
Klebsiella pneumoniae	30	15.9
Proteus mirabilis	8	4.3
Acinetobacter baumannii	5	2.7
Gram-Positive Organisms	**65**	**34.7**
Staphylococcus aureus	38	20.3
Enterococcus species	18	9.6
Coagulase-negative Staphylococci	9	4.8
Total	**187**	**100.0**

Gram-negative organisms predominated (65.3%), with Pseudomonas aeruginosa being the most common isolate (23.4%), followed by Escherichia coli (18.7%) and Klebsiella pneumoniae (15.9%). Among Gram-positive organisms (34.7%), Staphylococcus aureus was the most frequent (20.3%).

This Gram-negative predominance is consistent with studies from South India, differing from Western literature where Gram-positive organisms often predominate[10][11].

Antimicrobial Sensitivity Pattern

Gram-Negative Organisms

The antibiotic sensitivity pattern of major Gram-negative isolates is presented in Table 4.

Table 5: Antibiotic sensitivity pattern of Gram-negative organisms (percentage sensitive)

Antibiotic	Pseudomonas (n=44)	E. coli (n=35)	Klebsiella (n=30)
Ampicillin	9.1%	11.4%	10.0%
Amoxicillin-clavulanate	15.9%	22.9%	20.0%
Piperacillin-tazobactam	70.5%	68.6%	66.7%
Ceftriaxone	18.2%	20.0%	16.7%
Ceftazidime	31.8%	28.6%	26.7%
Cefoperazone sulbactam	65.9%	62.9%	63.3%
Imipenem	88.6%	91.4%	90.0%
Meropenem	86.4%	88.6%	86.7%
Ertapenem	-	85.7%	83.3%
Amikacin	79.5%	74.3%	76.7%
Gentamicin	56.8%	54.3%	53.3%
Ciprofloxacin	38.6%	34.3%	33.3%
Levofloxacin	45.5%	42.9%	40.0%
Cotrimoxazole	22.7%	25.7%	23.3%

Carbapenems (imipenem, meropenem) showed the highest sensitivity (86-91%) for Gram-negative organisms, followed by amikacin (74-80%) and piperacillin-tazobactam (67-71%). Third-generation cephalosporins showed poor sensitivity (17-31%), reflecting high ESBL production. Fluoroquinolone resistance was significant (55-67% resistance).

Gram-Positive Organisms

The antibiotic sensitivity pattern of Gram-positive organisms is shown in Table 5.

Table 6: Antibiotic sensitivity pattern of Gram-positive organisms (percentage sensitive)

Antibiotic	S. aureus (n=38)	Enterococcus (n=18)
Penicillin	13.2%	27.8%
Ampicillin	15.8%	55.6%
Oxacillin/Cefoxitin	55.3%	-
Erythromycin	36.8%	38.9%
Clindamycin	60.5%	44.4%
Gentamicin	63.2%	61.1%
Ciprofloxacin	42.1%	50.0%
Cotrimoxazole	55.3%	-
Vancomycin	100.0%	94.4%
Linezolid	100.0%	100.0%

Vancomycin and linezolid demonstrated excellent sensitivity (94-100%) against Gram-positive organisms. Gentamicin showed moderate sensitivity (61-63%). Resistance to penicillin was high (72-86%).

Resistance Patterns

Table 7: Antimicrobial resistance patterns

Resistance Pattern	Number	Percentage
ESBL production		
E. coli	21/35	60.0%
Klebsiella pneumoniae	18/30	60.0%
Proteus mirabilis	3/8	37.5%
Total ESBL	**42/73**	**57.5%**
Carbapenem resistance		
Pseudomonas aeruginosa	5/44	11.4%
Acinetobacter baumannii	3/5	60.0%
Total carbapenem resistance	**8/122**	**6.6%**
MRSA	17/38	44.7%
Vancomycin-resistant Enterococcus	1/18	5.6%

Extended-spectrum beta-lactamase (ESBL) production was detected in 57.5% of Enterobacteriaceae, with both E. coli and Klebsiella showing 60% ESBL rates.

Methicillin-resistant Staphylococcus aureus (MRSA) was present in 44.7% of S. aureus isolates. Carbapenem resistance was relatively low (6.6%), but its presence is concerning.

One case of vancomycin-resistant Enterococcus (VRE) was detected. These high resistance rates underscore the challenge of treating diabetic foot infections and the need for judicious antibiotic use.

Treatment Outcomes

Treatment modalities and outcomes are summarized in Table 6.

Table 8: Treatment modalities and outcomes (n=150)

Treatment Modality	Number	Percentage (%)
Conservative Management		
Antibiotics + wound care only	36	24.0
Debridement + antibiotics	71	47.3
Surgical Intervention		
Minor amputation (toe/forefoot)	28	18.7
Major amputation (below-knee)	13	8.7
Major amputation (above-knee)	2	1.3
Outcome		
Complete healing	92	61.3
Partial healing/improvement	15	10.0
Static/deterioration	-	-
Total amputations	43	28.7
Death	-	-
Mean hospital stay (days)	**18.6 ± 8.4**	

Debridement with antibiotics was the most common treatment approach (47.3%). Complete healing was achieved in 61.3% of cases, while 28.7% required amputation (minor: 18.7%, major: 10.0%). No mortality occurred during the study period.

Correlation Between Wagner's Grade and Outcome

The relationship between Wagner's grading and treatment outcomes showed strong statistical significance (Table 7).

Table 9: Correlation between Wagner's grade and treatment outcome

Wagner's Grade	Complete Healing	Partial Healing	Amputation Required	Total
Grade 1	24 (92.3%)	2 (7.7%)	0 (0.0%)	26
Grade 2	58 (89.2%)	5 (7.7%)	2 (3.1%)	65
Grade 3	10 (26.3%)	8 (21.1%)	20 (52.6%)	38
Grade 4	0 (0.0%)	0 (0.0%)	17 (100.0%)	17
Grade 5	0 (0.0%)	0 (0.0%)	4 (100.0%)	4
Total	**92**	**15**	**43**	**150**
$\chi^2 = 124.56$, $p < 0.001$ (highly significant)				

Wagner's grades 1 and 2 showed excellent healing rates (89-92%), with minimal amputation requirement (0-3%). In contrast, grade 3 ulcers had a 52.6% amputation rate, while grades 4 and 5 uniformly required amputation (100%). This correlation was highly significant ($p < 0.001$), validating Wagner's classification as a prognostic tool[12].

Factors Associated with Amputation

Multiple factors were analyzed for their association with amputation (Table 8).

Table 10: Factors associated with amputation

Factor	Amputation (n=43)	No Amputation (n=107)	p-value
Age > 60 years	24 (55.8%)	19 (17.8%)	< 0.001
HbA1c > 9%	32 (74.4%)	35 (32.7%)	< 0.001
Duration of DM > 10 years	31 (72.1%)	37 (34.6%)	< 0.001
Peripheral vascular disease	38 (88.4%)	44 (41.1%)	< 0.001
Smoking	24 (55.8%)	32 (29.9%)	0.003
Ulcer size > 5 cm²	35 (81.4%)	53 (49.5%)	< 0.001
Ulcer duration > 3 months	23 (53.5%)	17 (15.9%)	< 0.001
Polymicrobial infection	26 (60.5%)	32 (29.9%)	< 0.001
MRSA/ESBL organisms	31 (72.1%)	45 (42.1%)	0.001
Wagner's grade 3	41 (95.3%)	18 (16.8%)	< 0.001

Multiple factors showed significant association with amputation: age > 60 years, poor glycemic control (HbA1c > 9%), prolonged diabetes duration (> 10 years), peripheral vascular disease, smoking, larger ulcer size (> 5 cm²), delayed presentation (> 3 months), polymicrobial infection, presence of resistant organisms (MRSA/ESBL), and higher Wagner's grade (≥ 3). All associations were statistically significant ($p < 0.05$).

DISCUSSION

This study provides comprehensive insights into the clinicobacteriological profile and outcomes of diabetic foot ulcers in the Andhra Pradesh population served by Katuri Medical College & Hospital. Our findings reflect regional demographic patterns, bacteriological trends, and therapeutic challenges characteristic of South Indian populations.

Demographic and Clinical Profile

The mean age of 56.8 years in our study aligns with national trends, where diabetic complications typically manifest in the 5th-6th decade[13]. The male predominance (68.7%) is consistent with multiple Indian studies and may reflect occupational exposure, higher prevalence of smoking, and potentially delayed healthcare-seeking behavior among males in rural settings[14][15].

The predominance of rural residents (62.7%) and occupations involving manual labor (farmers 32%, laborers 23.3%) is particularly relevant to Andhra Pradesh's demographic profile. These populations face unique challenges including limited access to healthcare, delayed diagnosis, inadequate footwear, and occupational hazards such as agricultural injuries and walking barefoot (58% in our study). These factors significantly contribute to the development and progression of diabetic foot ulcers.

Poor glycemic control was evident, with mean HbA1c of 9.2% and 44.7% of patients having HbA1c > 9%. This reflects inadequate diabetes management at the community level, possibly due to poor awareness, non-compliance, limited access to healthcare, and socioeconomic constraints. The high prevalence of complications (peripheral vascular disease 54.7%, chronic kidney disease 22.7%) further emphasizes the systemic impact of prolonged, uncontrolled diabetes.

Ulcer Characteristics and Wagner's Grading

The predominance of Wagner's grade 2 ulcers (43.3%) in our study is consistent with multiple Indian studies[16][17]. However, the substantial proportion of advanced grades (grade 3: 25.3%, grades 4-5: 14.0%) indicates delayed presentation and highlights the need for early detection and intervention programs.

The plantar forefoot location (45.3%) reflects the biomechanics of neuropathic ulceration, where pressure points during walking lead to repeated microtrauma in the setting of sensory loss. The near-universal presence of neuropathy (92%) in our cohort is consistent with the pathophysiology of diabetic foot ulcers, where loss of protective sensation is a critical factor[18].

The delayed presentation (48% with ulcers lasting 1-3 months) is concerning and likely contributes to poorer outcomes. This delay may reflect limited healthcare access, lack of awareness about foot care, and socioeconomic barriers in rural populations.

Bacteriological Profile

Our study revealed Gram-negative predominance (65.3%), with Pseudomonas aeruginosa (23.4%), E. coli (18.7%), and Klebsiella pneumoniae (15.9%) being the most common isolates. This pattern is consistent with multiple studies from South India but contrasts with Western literature where Gram-positive organisms, particularly Staphylococcus aureus, often predominate[19][20].

Several factors may explain this regional variation:

1. Environmental factors: Hot, humid tropical climate of Andhra Pradesh favors Gram-negative colonization
2. Hygiene and sanitation: Rural settings with limited access to clean water and sanitation
3. Footwear practices: Walking barefoot (58% in our study) increases environmental exposure
4. Delayed presentation: Chronic ulcers tend to have more Gram-negative colonization
5. Prior antibiotic use: Though we excluded patients on antibiotics > 48 hours, community antibiotic use may influence flora.

The high rate of polymicrobial infections (38.7%) is clinically significant, as these infections are associated with more severe tissue destruction, poorer outcomes, and higher amputation rates, as demonstrated in our analysis ($p < 0.001$)[21].

Pseudomonas aeruginosa as the leading pathogen is particularly concerning due to its virulence factors, biofilm formation capacity, and intrinsic resistance mechanisms. Its prevalence in our setting necessitates anti-pseudomonal coverage in empirical regimens.

Antimicrobial Resistance Patterns

The antimicrobial resistance patterns observed in our study reflect the global crisis of antimicrobial resistance, particularly severe in Indian healthcare settings. The ESBL production rate of 57.5% among Enterobacteriaceae (E. coli 60%, Klebsiella 60%) is alarmingly high and consistent with other Indian studies reporting ESBL rates of 50-70%[22][23].

MRSA prevalence of 44.7% in our study is significant and highlights the dual challenge of Gram-negative ESBL producers and Gram-positive MRSA in diabetic foot infections. This necessitates broad-spectrum empirical therapy covering both resistant Gram-negatives and MRSA.

The relatively low carbapenem resistance (6.6%) is encouraging, preserving carbapenems as effective options for severe infections. However, the detection of any carbapenem resistance is concerning, as these are last-line agents. Strict carbapenem stewardship is essential to prevent further resistance development.

The excellent sensitivity to vancomycin (100% for S. aureus, 94.4% for Enterococcus) and linezolid (100% for both) provides reliable options for resistant Gram-positive infections. However, the detection of one VRE case signals the need for continued surveillance.

Treatment Outcomes

The overall healing rate of 61.3% in our study is comparable to other Indian studies but lower than Western reports (75-80%)[24]. This difference likely reflects multiple factors:

- Later presentation (48% with ulcers > 1 month)
- Higher proportion of advanced Wagner grades (39.3% grade ≥ 3)
- Higher prevalence of peripheral vascular disease (54.7%)
- Poorer glycemic control (mean HbA1c 9.2%)
- Higher rates of resistant organisms (ESBL 57.5%, MRSA 44.7%)
- Socioeconomic factors affecting compliance and follow-up

The amputation rate of 28.7% (minor 18.7%, major 10.0%) is concerning but consistent with Indian studies reporting rates of 20-35%[25]. The strong correlation between Wagner's grade and amputation risk validates the use of this classification system for prognostication and clinical decision-making.

Prognostic Factors

Our analysis identified multiple independent risk factors for amputation, with Wagner's grade ≥ 3 showing the strongest association (95.3% of amputations occurred in grade ≥ 3, $p < 0.001$). This emphasizes the importance of early intervention before ulcers progress to advanced grades.

Other significant factors included:

- Peripheral vascular disease (88.4% of amputations): Impairs healing through reduced tissue perfusion
- Poor glycemic control (HbA1c > 9% in 74.4% of amputations): Affects neutrophil function, collagen synthesis, and microvascular circulation
- Ulcer size and duration: Larger (> 5 cm^2) and chronic ulcers (> 3 months) had significantly higher amputation rates
- Polymicrobial and resistant organisms: 60.5% of amputations had polymicrobial infections; 72.1% had MRSA/ESBL organisms
- Age and smoking: Older age (> 60 years) and smoking both significantly increased amputation risk

These findings underscore the multifactorial nature of diabetic foot outcomes and the need for comprehensive, multidisciplinary management addressing each risk factor.

Clinical Implications

Based on our findings, we propose the following recommendations for diabetic foot ulcer management in similar settings:

1. Empirical antibiotic regimen: Given the predominance of Gram-negative ESBL producers and MRSA, we recommend:
- First-line: Piperacillin-tazobactam or cefoperazone-sulbactam + vancomycin or linezolid
- Severe infections or suspected ESBL: Carbapenem (imipenem/meropenem) + vancomycin
- Modify based on culture sensitivity reports within 48-72 hours

2. Early screening and prevention: Universal foot screening for all diabetic patients, particularly those with:

- Diabetes duration > 10 years
- Poor glycemic control (HbA1c > 8%)
- Neuropathy or peripheral vascular disease
- Previous foot ulcer history

3. Multidisciplinary approach: Integration of:
- Endocrinology (glycemic control optimization)
- Vascular surgery (for critical limb ischemia)
- Podiatry/orthotic services (pressure offloading, custom footwear)
- Wound care specialists (advanced dressings, negative pressure therapy)
- Infectious disease consultation (for resistant organisms)

4. Patient education: Structured education programs focusing on:
- Daily foot inspection and hygiene
- Appropriate footwear (avoid walking barefoot)
- Immediate reporting of minor injuries
- Importance of glycemic control
- Smoking cessation

5. Community-level interventions: Given the rural predominance:
- Mobile diabetes clinics for rural areas
- Training of primary health center staff in foot examination
- Community awareness campaigns
- Subsidized or free footwear programs for high-risk patients

Limitations

Several limitations of this study should be acknowledged:

1) Single-center study: Findings may not be generalizable to other regions of India
2) Sample size: While adequate for analysis, larger multicenter studies would provide more robust data
3) Follow-up duration: Limited to hospital stay and immediate post-discharge period; long-term outcomes (recurrence rates, quality of life) were not assessed
4) Anaerobic culture: Routine anaerobic culture was not performed, potentially underestimating anaerobic contribution
5) Biofilm assessment: Biofilm formation capability was not systematically evaluated
6) Molecular resistance mechanisms: Genotypic resistance mechanisms were not characterized
7) Cost-effectiveness analysis: Economic impact and cost-effectiveness of different interventions were not evaluated

Despite these limitations, this study provides valuable region-specific data to guide clinical practice in Andhra Pradesh and similar settings.

CONCLUSION

This study demonstrates that diabetic foot ulcers in Andhra Pradesh are characterized by a predominance of Gram-negative multidrug-resistant organisms, with Pseudomonas aeruginosa, E. coli, and Klebsiella pneumoniae being the leading pathogens. High rates of ESBL production (57.5%) and MRSA (44.7%) pose significant therapeutic challenges.

Wagner's grading system effectively stratifies patients by risk, with grades 3 and above showing dramatically increased amputation rates (52.6-100%). Multiple factors including peripheral vascular disease, poor glycemic control, delayed presentation, and resistant organisms significantly impact outcomes.

The findings emphasize the need for:

1) Culture-guided antibiotic therapy with initial broad-spectrum coverage
2) Early detection through systematic screening programs
3) Aggressive glycemic control and vascular assessment
4) Multidisciplinary team approach to management
5) Community-level education and prevention initiatives
6) Antimicrobial stewardship to combat rising resistance

With appropriate early intervention and comprehensive management, amputation rates can be reduced, improving quality of life and reducing the socioeconomic burden of diabetic foot complications in Andhra Pradesh.

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