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ANTIMICROBIAL SUSCEPTIBILITY PATTERNS IN DIABETIC FOOT ULCERS AT A TERTIARY CARE TEACHING HOSPITAL IN SOUTH INDIA

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ABSTRACT
Background: Diabetic foot ulcers (DFUs) are a major complication of diabetes mellitus, frequently leading to severe infection, prolonged hospitalisation, and increased risk of amputation. Understanding local microbial profiles and antimicrobial susceptibility patterns is essential for guiding empirical therapy and antimicrobial stewardship. This study evaluated the antimicrobial susceptibility patterns of pathogens isolated from DFUs at a tertiary care teaching hospital in South India.
Methods: We retrospectively analysed 100 patients with culture-proven diabetic foot infections treated at Saveetha Medical College and Hospital, Chennai, over a one-year period from January 2023 to January 2024. Demographic, clinical, microbiological, and antimicrobial susceptibility data were extracted from hospital records. Susceptibility testing was performed using the Kirby-Bauer disk diffusion method and interpreted according to CLSI guidelines.
Results: A total of 150 microbial isolates were obtained from 100 patients; polymicrobial infection was noted in 25% of cases. The predominant organisms were Staphylococcus aureus (30%), Pseudomonas aeruginosa (25%), Escherichia coli (20%), and Klebsiella pneumoniae (15%). S. aureus showed high resistance to penicillin (85%) and methicillin (40%) but remained largely sensitive to vancomycin (95%) and linezolid (90%). P. aeruginosa showed significant resistance to ciprofloxacin (60%) and ceftazidime (50%) but was largely sensitive to piperacillin-tazobactam (85%) and meropenem (80%). E. coli and K. pneumoniae showed resistance to third-generation cephalosporins (70% and 60%, respectively) but remained largely sensitive to carbapenems (90% for both). Most patients (80%) showed clinical improvement with appropriate antimicrobial therapy, 10% required surgical intervention, and mortality was 5%.
Conclusion: Multidrug-resistant organisms were common among pathogens isolated from DFUs in this cohort. Empirical antibiotic selection guided by local susceptibility patterns, supported by ongoing microbial surveillance and antimicrobial stewardship, is essential for improving outcomes and limiting further resistance in diabetic foot infections.

KEYWORDS: Diabetic foot ulcers; antimicrobial susceptibility; tertiary care; multidrug-resistant organisms; Chennai

INTRODUCTION

Diabetic foot ulcers (DFUs) are a major complication of diabetes mellitus and one of its most costly and disabling long-term consequences, contributing substantially to hospitalisation, lower-extremity amputation, and reduced quality of life worldwide [1,2]. Infection is among the most common precipitants of hospitalisation and amputation in patients with DFUs, and the risk of infection rises with peripheral neuropathy, peripheral arterial disease, wound depth, and a history of prior ulceration or amputation [3].
The microbial aetiology of diabetic foot infections is diverse and varies by geography, wound chronicity, and prior antibiotic exposure, ranging from monomicrobial Gram-positive infections in previously untreated superficial ulcers to polymicrobial infections, often involving multidrug-resistant Gram-negative organisms, in chronic or previously treated wounds [4]. International guidelines recommend that empirical antibiotic selection be guided by local microbial epidemiology and susceptibility data, reserving broad-spectrum or reserve agents for patients at higher risk of resistant organisms, underscoring the importance of periodic local surveillance of the kind undertaken in this study [5].
This study aims to analyse the antimicrobial susceptibility of pathogens isolated from DFUs at Saveetha Medical College and Hospital, Chennai, Tamil Nadu, India, in order to inform local empirical antibiotic selection and antimicrobial stewardship efforts.

2. Methods

2.1 Study Design

This is a retrospective observational study conducted over one year, from January 2023 to January 2024.

2.2 Setting

The study was carried out at Saveetha Medical College and Hospital, a tertiary care teaching hospital located in Chennai, Tamil Nadu, India.

2.3 Study Population
The study population comprised 100 patients diagnosed with diabetic foot ulcers. Inclusion criteria were: patients with clinically diagnosed DFUs, and patients with culture-proven microbial infections.

2.4 Data Collection
Data were collected from medical records, including patient demographics, clinical presentation, microbial isolates, and antibiotic susceptibility patterns. Variables collected included age, sex, duration of diabetes, ulcer characteristics, microbial isolates, and antibiotic resistance profiles.

2.5 Microbiological Analysis
Samples from DFUs were collected using sterile technique and processed in the microbiology laboratory. Identification of microbial isolates was performed using standard biochemical methods. Antimicrobial susceptibility testing was conducted using the Kirby-Bauer disk diffusion method, and results were interpreted according to Clinical and Laboratory Standards Institute (CLSI) guidelines [6].

2.6 Statistical Analysis
Descriptive statistics summarised patient demographics, microbial isolates, and antimicrobial susceptibility patterns. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Analysis was performed using SPSS 2023.

3. RESULTS

3.1 Patient Demographics
The study included 100 patients, with 60 males (60%) and 40 females (40%), and an average age of 58.3 ± 12.7 years. The mean duration of diabetes was 15.2 ± 7.8 years. Most patients (85%) had type 2 diabetes mellitus.

Table 1. Patient demographics.

Characteristic	Value
Total patients	100
Mean age (± SD), years	58.3 ± 12.7
Mean duration of diabetes (± SD), years	15.2 ± 7.8
Type 2 diabetes mellitus, %	85%
Male, n (%)	60 (60%)
Female, n (%)	40 (40%)

3.2 Clinical Presentation
The majority of ulcers were located on the forefoot (65%), followed by the midfoot (20%) and heel (15%). Ulcer grades were classified according to the Wagner classification, with 50% of patients having grade 2 ulcers, 30% having grade 3, and 20% having grade 4.

Table 2. Ulcer location.

Ulcer location	n	%
Forefoot	65	65%
Midfoot	20	20%
Heel	15	15%
Total	100	100%

Table 3. Wagner grade distribution.

Wagner grade	n	%
Grade 2	50	50%
Grade 3	30	30%
Grade 4	20	20%
Total	100	100%

3.3 Microbial Isolates

A total of 150 microbial isolates were obtained from 100 patients. The most common organisms were Staphylococcus aureus (30%), Pseudomonas aeruginosa (25%), Escherichia coli (20%), and Klebsiella pneumoniae (15%). Polymicrobial infections were noted in 25% of cases.

Table 4. Microbial isolates (n = 150 isolates from 100 patients; 25% polymicrobial).

Organism	% of isolates
Staphylococcus aureus	30%
Pseudomonas aeruginosa	25%
Escherichia coli	20%
Klebsiella pneumoniae	15%
Other/unspecified organisms	~10%

3.4 Antimicrobial Susceptibility Patterns

Staphylococcus aureus isolates showed high resistance to penicillin (85%) and methicillin (40%), but were largely sensitive to vancomycin (95%) and linezolid (90%). Pseudomonas aeruginosa exhibited significant resistance to ciprofloxacin (60%) and ceftazidime (50%), while remaining sensitive to piperacillin-tazobactam (85%) and meropenem (80%). Escherichia coli and Klebsiella pneumoniae isolates demonstrated resistance to third-generation cephalosporins (70% and 60%, respectively), but were sensitive to carbapenems (90% for both).

Table 5. Antimicrobial susceptibility patterns of the four predominant organisms.

Organism	Antibiotic	Result
Staphylococcus aureus	Penicillin	85% resistant
Staphylococcus aureus	Methicillin	40% resistant
Staphylococcus aureus	Vancomycin	95% sensitive
Staphylococcus aureus	Linezolid	90% sensitive
Pseudomonas aeruginosa	Ciprofloxacin	60% resistant
Pseudomonas aeruginosa	Ceftazidime	50% resistant
Pseudomonas aeruginosa	Piperacillin-tazobactam	85% sensitive
Pseudomonas aeruginosa	Meropenem	80% sensitive
Escherichia coli	3rd-generation cephalosporins	70% resistant
Escherichia coli	Carbapenems	90% sensitive
Klebsiella pneumoniae	3rd-generation cephalosporins	60% resistant
Klebsiella pneumoniae	Carbapenems	90% sensitive

3.5 Outcomes

The mean duration of hospital stay was 18.6 ± 7.5 days. Most patients (80%) showed clinical improvement with appropriate antimicrobial therapy, while 10% required surgical intervention. The mortality rate was 5%.

Table 6. Clinical outcomes (mean hospital stay 18.6 ± 7.5 days).

Outcome	n	%
Clinical improvement	80	80%
Surgical intervention	10	15%
Mortality	5	5%

4. DISCUSSION

4.1 Interpretation of Results

The predominance of Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, and Klebsiella pneumoniae among our isolates is consistent with the polymicrobial, mixed Gram-positive/Gram-negative picture reported elsewhere in South India. In a South-Indian tertiary hospital series from Manipal, 354 aerobic isolates were recovered from 213 DFU patients, with Gram-negative organisms accounting for just over half of all isolates and polymicrobial infection present in roughly half of cases [7]. A more recent South Indian series similarly reported Gram-negative organisms among the large majority of isolates (88%), with Escherichia coli and Klebsiella pneumoniae again among the leading pathogens [8]. Our cohort's approximately even split between Gram-positive Staphylococcus aureus (30%) and the combined Gram-negative organisms (60% across the three species reported), with polymicrobial infection in 25% of cases, falls broadly within this reported range, though the precise Gram-positive:Gram-negative ratio in DFU cohorts appears to vary appreciably by centre and population [7,8].

The methicillin resistance rate of 40% among our Staphylococcus aureus isolates is somewhat lower than the 56% methicillin resistance and 72% overall multidrug-resistant-organism positivity reported in an earlier Indian tertiary-hospital series, in which multidrug resistance was independently associated with peripheral neuropathy, coexisting osteomyelitis, larger ulcer size, and poorer glycaemic control [9]. High resistance to penicillin (85%) among our S. aureus isolates, alongside near-universal susceptibility to vancomycin (95%) and linezolid (90%), reinforces current guidance that these agents remain reliable options for confirmed or suspected methicillin-resistant S. aureus infection, while penicillin and, increasingly, methicillin-class agents cannot be relied upon empirically [5].

Among Gram-negative isolates, resistance to ciprofloxacin (60%) and ceftazidime (50%) in Pseudomonas aeruginosa, and to third-generation cephalosporins in Escherichia coli (70%) and Klebsiella pneumoniae (60%), mirrors a broader regional pattern of fluoroquinolone and cephalosporin resistance among Enterobacteriaceae and non-fermenting Gram-negative bacilli in Indian diabetic foot infections [4,9]. High susceptibility to piperacillin-tazobactam, meropenem, and carbapenems generally in our cohort is reassuring, but it also reflects a growing reliance on broad-spectrum and last-line agents, a pattern with implications for future resistance if not accompanied by active antimicrobial stewardship [4,5].

4.2 Strengths and Limitations

Strengths of the study include a reasonably large sample size and comprehensive analysis of antimicrobial susceptibility patterns across the major pathogens implicated in DFUs. Limitations include the retrospective, single-centre design, which may limit generalisability, together with several internal inconsistencies in the reported data that should be clarified before submission: the four named organisms account for 90% of the 150 isolates, leaving roughly 10% (approximately 15 isolates) attributable to organisms not specified in the dataset.

4.3 Implications for Practice

The findings underscore the importance of regular microbial surveillance and susceptibility testing to guide effective treatment strategies for DFUs in this setting. Healthcare providers should consider local resistance patterns, rather than generic empirical regimens, when selecting antibiotics for suspected diabetic foot infections, reserving carbapenems and other broad-spectrum agents for culture-confirmed multidrug-resistant organisms wherever possible [5].

5. CONCLUSION

The study conducted at Saveetha Medical College and Hospital demonstrates the importance of understanding antimicrobial susceptibility patterns in managing diabetic foot ulcers. Tailored antibiotic therapy, guided by local resistance patterns and supported by ongoing surveillance and antimicrobial stewardship, is crucial for effective treatment and improved patient outcomes.

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REFERENCES

1. Boulton AJ, Vileikyte L, Ragnarson-Tennvall G, Apelqvist J. The global burden of diabetic foot disease. Lancet. 2004;366(9498):1719–1724.
2. Singh N, Armstrong DG, Lipsky BA. Preventing foot ulcers in patients with diabetes. JAMA. 2005;293(2):217–228.
3. Lavery LA, Armstrong DG, Wunderlich RP, Mohler MJ, Wendel CS, Lipsky BA. Risk factors for foot infections in individuals with diabetes. Diabetes Care. 2006;29(6):1288–1293.
4. Richard JL, Sotto A, Lavigne JP. New insights in diabetic foot infection. World J Diabetes. 2011;2(2):24–32.
5. Lipsky BA, Berendt AR, Cornia PB, et al. 2012 Infectious Diseases Society of America clinical practice guideline for the diagnosis and treatment of diabetic foot infections. Clin Infect Dis. 2012;54(12):e132–e173.
6. Clinical and Laboratory Standards Institute. Performance Standards for Antimicrobial Susceptibility Testing. CLSI Supplement M100. 30th ed. Wayne, PA: CLSI; 2020.

7. Sekhar SM, Unnikrishnan MK, Rodrigues GS, Vyas N, Mukhopadhyay C. Antimicrobial susceptibility pattern of aerobes in diabetic foot ulcers in a South-Indian tertiary care hospital. Foot (Edinb). 2018;37:95–100.
8. Govindaswamy S, Subbarayan E, Jaishwanth VM, Anantha Kumar SS, Santhosh S, Renji SA. Bacteriological profile and antimicrobial susceptibility patterns in patients with diabetic foot infections in a tertiary care hospital in South India. J Pure Appl Microbiol. 2025;19(3):1948–1954.
9. Gadepalli R, Dhawan B, Sreenivas V, Kapil A, Ammini AC, Chaudhry R. A clinical microbiological study of diabetic foot ulcers in an Indian tertiary care hospital. Diabetes Care. 2006;29(8):1727–1732.