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Microbiological Profile and Antibiotic Resistance in Diabetic Foot Infections: A Retrospective Study from Marrakech

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Abstract

Introduction: Diabetic foot infection (DFI) is a severe complication of diabetes, often leading to hospitalization and amputation. This study aimed to describe the causative pathogens and their antimicrobial resistance patterns.

Methods: We conducted a retrospective study of 146 patients hospitalized for DFI at Avicenne Military Hospital, Marrakech, between 2018 and 2023. Clinical data, microbiological results, and antibiotic susceptibility profiles were collected and analyzed according to CASFM/EUCAST (Comité De l'Antibiogramme de la Société Française de Microbiologie/European Committee on Antimicrobial Susceptibility Testing) 2025 guidelines.

Results: The mean age was 63.27 years, with a male predominance (125, 86%) and type 2 diabetes in 90% (131) of cases. A total of 146 bacterial isolates were identified, mainly Gram-negative bacilli (104, 71.2%), with Enterobacterales being the most frequent (87, 60%). The most frequent species were Escherichia coli (26, 17.8%), Klebsiella pneumoniae (21, 14.3%), Pseudomonas aeruginosa (16, 11%), and Staphylococcus aureus (15, 10.3%). Enterobacterales showed high resistance to ampicillin (84%), amoxicillin-clavulanic acid (81%), and ciprofloxacin (57%), while susceptibility to imipenem and amikacin remained high. Pseudomonas aeruginosa was also susceptible to these agents, and Staphylococcus aureus isolates were uniformly susceptible to vancomycin and ciprofloxacin.

Conclusion: DFIs in Marrakech are characterized by a predominance of multidrug-resistant Gram-negative bacilli. These findings emphasize the importance of rational antibiotic use, infection control, and continuous microbiological surveillance.

Keywords: Antibiotic Resistance; Diabetic Foot; Infection; Marrakech; Microbiology

1. Introduction

Diabetic foot refers to all infectious, ulcerative, or necrotic lesions of the foot occurring in patients with diabetes, typically associated with peripheral neuropathy and/or peripheral arterial disease [1]. This complication affects approximately 15% to 25% of diabetic patients [2] and is frequently complicated by secondary infection, reported in 25% to 80% of cases [2].

Diabetic foot infection represents a leading cause of hospitalization, morbidity, and non-traumatic amputation, with substantial socio-economic and psychological consequences [3]. The risk of amputation can be up to 155 times higher in patients with DFI [4]. The condition often progresses insidiously, beginning with superficial tissue involvement and potentially extending to deep tissues or bone. Early, multidisciplinary management is therefore crucial, including

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vascular and neurological assessment, surgical debridement, targeted microbiological sampling, appropriate antibiotic therapy, and optimal glycemic control.

In Morocco, epidemiological data on amputations related to DFI are limited, unlike in countries such as France, where diabetic foot represents the leading cause of lower limb amputation, affecting approximately 8,000 patients annually [2].

The objective of this study was to describe the microbiological profile of DFIs and to evaluate the antibiotic susceptibility patterns of the isolated pathogens.

2. Materials and methods

We conducted a retrospective descriptive study of 146 patients hospitalized for diabetic foot infections at Avicenne Military Hospital, Marrakech, between February 2018 and May 2023. Patients with foot ulcers or infections in a diabetic context were included, while non-diabetic patients, admissions outside the study period, or incomplete records were excluded.

Clinical and microbiological data were collected from medical records using a standardized electronic data sheet and analyzed with Microsoft Excel.

Microbiological samples were collected from clinically infected wounds after proper wound cleaning and debridement. Depending on the wound, sampling methods included superficial swabs, deep curettage, tissue biopsy, or fine needle aspiration. Samples were transported promptly to the laboratory in appropriate media. Laboratory analysis included macroscopic and microscopic examination, culture on selective and enriched media, and bacterial identification using Gram staining, colony morphology, biochemical tests, API strips, or automated systems.

Antibiotic susceptibility testing was performed for all bacterial isolates using disk diffusion, broth microdilution, or automated methods, and interpreted according to CASFM/EUCAST 2025 guidelines [5].

3. Results

A total of 146 patients were included, with a mean age of 63.27 years (range 37-86), predominantly males (86%). Type 2 diabetes was the most common (90%), with a mean duration of 13.44 years. Most patients were treated with insulin (72%) (Figure *1*).

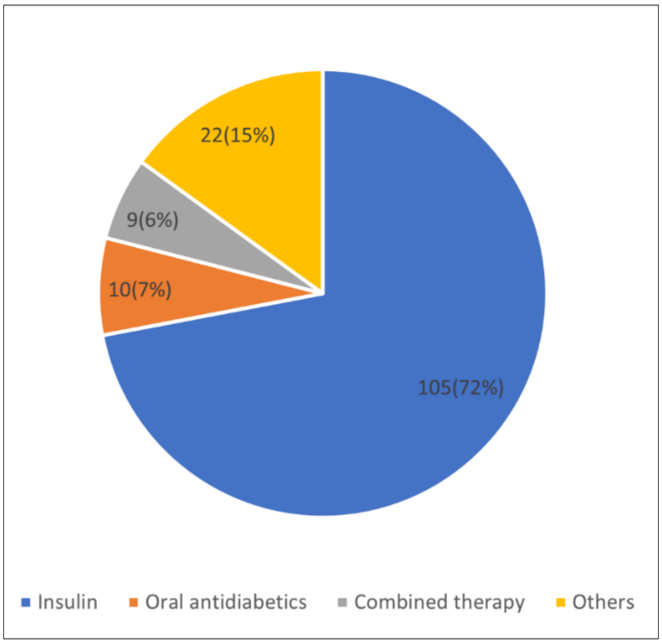

Figure 1 Treatment regimens among patients (n=146)

Microbiological analysis yielded 146 bacterial isolates from clinically infected wounds. Gram-negative bacilli (71.2%) were more frequent than Gram-positive cocci (28.7%). Enterobacterales were the most frequent (60%), followed by staphylococci (14%), non-fermenting Gram-negative bacilli (11%), and streptococci (10%) (Figure *2*). The most common species were *Escherichia coli* (17.8%), *Klebsiella pneumoniae* (14.3%), *Pseudomonas aeruginosa* (11%), and *Staphylococcus aureus* (10.3%).

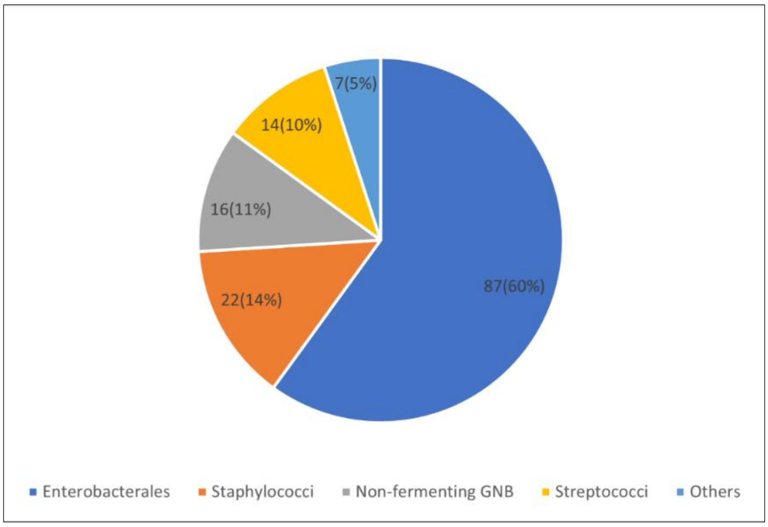

Figure 2 Distribution of major bacterial groups (n=146)

In our study, we analyzed the resistance patterns of the most frequently isolated bacteria. The detailed antibiotic resistance rates of the main bacterial species are summarized in Table *1*.

Table 1 Antibiotic resistance rates of main bacterial isolates

Bacterial species	Main antibiotic resistances	Most effective antibiotics
Enterobacterales (n=87)	AMP 84%, AMC 81%, TIC 67%, SXT 58%, CIP 57%	IMI, AMK
Escherichia coli (n=26)	AMP 76%, TIC 71%, AMC 69%, CIP 58%, SXT 58%, TZP 42%, CRO 29%, FOS 19%	IMI 8%, GEN 4%, AMK 8%
Klebsiella pneumoniae (n=21)	AMC 75%, CIP 76%, SXT 71%, TZP 48%, GEN 43%, CRO 33%, FOS 40%, IMI 31%	AMK 0% (all susceptible)
Pseudomonas aeruginosa (n=16)	TIC 69%, CIP 44%, FOS 28%, ATM 22%, GEN 13%, CAZ 13%, TZP 13%	IMI 6%, AMK 6%
Staphylococcus aureus (n=15)	PEN 92%, MRSA 25%, GEN 20%, FUS 20%, TOB 13%, SXT 10%, RIF 7%	VAN 0%, CIP 0% (all susceptible)

AMP = ampicillin; AMC = amoxicillin-clavulanic acid; TIC = ticarcillin; SXT = trimethoprim-sulfamethoxazole; CIP = ciprofloxacin; IMI = imipenem; AMK = amikacin; TZP = piperacillin-tazobactam; CRO = ceftriaxone; FOS = fosfomycin; GEN = gentamicin; CAZ = ceftazidime; ATM = aztreonam; FUS = fusidic acid; TOB = tobramycin; RIF = rifampicin; VAN = vancomycin; MRSA = methicillin-resistant S. aureus.

Overall, Enterobacterales were highly resistant to β-lactams and fluoroquinolones but remained susceptible to imipenem and amikacin. *Pseudomonas aeruginosa* showed similar susceptibility patterns. *Staphylococcus aureus* isolates were fully susceptible to vancomycin and ciprofloxacin.

4. Discussion

In our series of 146 patients, the mean age was 63.27 years, similar to previous reports [6]. Male predominance (86%) was also observed in other studies [6,7]. Type 2 diabetes was the most common form (90%), consistent with the literature [8,9], with a mean duration of 13.44 years, comparable to 12.5 and 11.7 years reported in these studies. Most patients were treated with insulin (72%), in line with previous findings [10].

Bacteriological sampling is a cornerstone in DFI management. Deep techniques such as curettage, aspiration, and biopsy are preferred for their diagnostic accuracy. Although these methods were used in our study, their individual frequencies could not be determined due to the retrospective design.

Unlike classical reports showing Gram-positive cocci predominance, our results revealed a majority of Gram-negative bacilli (71.2%), mainly Enterobacterales (60%), consistent with data from Africa and Asia [11,12]. *E.coli* was the most frequent isolate (17.8%), comparable to other series [13,14]. *Streptococcus spp.* Accounted for 9.6%, slightly higher than in previous studies [13,15,16], whereas *S. aureus* represented 10.3%, lower than reported elsewhere [7,16]. *Pseudomonas aeruginosa* was isolated in 11% of cases, a rate similar to other findings [13,17].

Regarding antimicrobial resistance, all *S. aureus* strains were susceptible to vancomycin, while rifampicin was effective in 93% of isolates, in accordance with earlier studies [18,19]. Methicillin resistance was detected in 25% of *S. aureus*, similar to previously reported rates [20,21]. Enterobacterales showed high resistance to beta-lactams, particularly amoxicillin and ticarcillin, while maintaining susceptibility to aminoglycosides and imipenem. Ceftriaxone resistance was 30%, close to the 28% reported elsewhere [22]; ampicillin resistance reached 76% compared to 48% in another series [18].

Pseudomonas aeruginosa exhibited 13% resistance to piperacillin, lower than in other reports [15,18], while resistance to other beta-lactams, aminoglycosides, and fluoroquinolones was intermediate compared to the literature [15,19].

Overall, our findings emphasize the predominance of multidrug-resistant Gram-negative bacilli in DFI and highlight the importance of targeted antibiotic therapy based on local microbiological surveillance.

This study is limited by its retrospective design, which led to incomplete medical records and loss of follow up for some patients. Important details were often missing, including the type of microbiological sample collected, culture outcomes (sterile, monomicrobial, or polymicrobial), detection of multidrug-resistant bacteria, classification of diabetic foot infections according to the International Consensus, antibiotic regimen and duration, and patient clinical evolution. These factors may have influenced the completeness and interpretation of our findings.

5. Conclusion

Diabetic foot infections are a common cause of hospitalization, associated with high morbidity, long antibiotic courses, and increased risk of amputation. Our study demonstrates a predominance of Gram-negative bacilli, particularly Escherichia coli, with high resistance to several commonly used antibiotics.

These findings underscore the importance of rational antibiotic use guided by local susceptibility patterns, strict hygiene, and preventive measures. To combat the growing threat of bacterial resistance, continuous microbiological surveillance, targeted healthcare staff training, and public awareness are essential to reduce treatment failures and preserve antibiotic efficacy.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest regarding this paper.

Statement of informed consent

The study was carried out without any interaction with individuals, making informed consent unnecessary.

Availability of data and materials

The data and materials used to support the findings of this study are publicly available.

References

[1] Chidiac, C. (2006). *Management of infected diabetic foot.* French-Language Infectious Diseases Society (SPILF).

[2] Magnan, C., Pantel, A., Dubois, A., et al. (2022). Pathophysiology, ecology and microbiological diagnosis of osteitis of the foot in patients living with diabetes mellitus. Revue Francophone des Laboratoires, 2022(545), 36–44. https://doi.org/10.1016/S1773-035X(22)00311-2

[3] Boutoille, D., Féraille, A., Maulaz, D., and Krempf, M. (2008). Quality of life with diabetes-associated foot complications: Comparison between lower limb amputation and chronic foot ulceration. Foot and Ankle International, 29(11), 1074–1078. https://doi.org/10.3113/FAI.2008.1074

[4] Lavery, L. A., Armstrong, D. G., Wunderlich, R. P., Mohler, M. J., Wendel, C. S., and Lipsky, B. A. (2006). Risk factors for foot infections in individuals with diabetes. Diabetes Care, 29(6), 1288–1293. https://doi.org/10.2337/dc05-2425

[5] CASFM/EUCAST. (2025). Recommendations of the Antibiogram Committee of the French Society of Microbiology / European Committee on Antimicrobial Susceptibility Testing (version 2025). https://www.sfm-microbiologie.org/wp-content/uploads/2025/07/CASFM2025_V1.1-JUILLET-2025.pdf

[6] Zemmouri, A., Tarchouli, M., Benbouha, A., et al. (2015). Bacteriological profile of diabetic foot and its impact on the choice of antibiotics. Pan African Medical Journal, 20, 1–7. https://doi.org/10.11604/pamj.2015.20.148.5853

[7] Selvarajan, S., Dhandapani, S., R. A., T. L., and Lakshmanan, A. (2021). Bacteriological profile of diabetic foot ulcers and detection of methicillin-resistant Staphylococcus aureus and extended-spectrum β-lactamase producers in a tertiary care hospital. Cureus. https://doi.org/10.7759/cureus.20596

[8] Laidi, S., El Aziz, S., & Chadli, A. (2016). Management of infected diabetic foot at Ibn Rochd University Hospital in Casablanca: about 244 cases. Annales d'Endocrinologie, 77(4), 498–528. https://doi.org/10.1016/j.ando.2016.07.805

[9] Djibril, A. M., Mossi, E. K., Djagadou, A. K., Balaka, A., Tchamdja, T., & Moukaila, R. (2018). Diabetic foot: epidemiological, diagnostic, therapeutic, and evolutionary aspects at the medico-surgical clinic of Sylvanus Olympio University Hospital in Lomé. Pan African Medical Journal, 30, Article 4. https://doi.org/10.11604/pamj.2018.30.4.14765

[10] Ouarradi, A. E. L. (2019). Diabetic foot: epidemiological, therapeutic, and prognostic profile (Doctoral thesis, Faculty of Medicine and Pharmacy, Marrakech).

[11] Sen, P., Demirdal, T., and Emir, B. (2019). Meta-analysis of risk factors for amputation in diabetic foot infections. Diabetes/Metabolism Research and Reviews, 35(3), e3175. https://doi.org/10.1002/dmrr.3165

[12] Citron, D. M., Goldstein, E. J., Merriam, C. V., Lipsky, B. A., and Abramson, M. A. (2007). Bacteriology of moderate-to-severe diabetic foot infections and in vitro activity of antimicrobial agents. Journal of Clinical Microbiology, 45(9), 2819–2828. https://doi.org/10.1128/JCM.00551-07

[13] Jouhar, L., Jaafar, R. F., Nasreddine, R., Itani, O., Haddad, F., Rizk, N., and Hoballah, J. J. (2020). Microbiological profile and antimicrobial resistance among diabetic foot infections in Lebanon. International Wound Journal, 17(6), 1764–1773. https://doi.org/10.1111/iwj.13465

[14] Durgad, S., Koticha, A., Nataraj, G., Deshpande, A., and Mehta, P. (2014). Diabetic foot ulcers—where do we stand microbiologically? International Journal of Diabetes in Developing Countries, 34(3), 169–173. https://doi.org/10.1007/s13410-013-0180-9

[15] Turhan, V., Mutluoglu, M., Acar, A., et al. (2013). Increasing incidence of Gram-negative organisms in bacterial agents isolated from diabetic foot ulcers. Journal of Infection in Developing Countries, 7(10), 707–712. https://doi.org/10.3855/jidc.2967

[16] Mendes, J. J., Marques-Costa, A., Vilela, C., et al. (2012). Clinical and bacteriological survey of diabetic foot infections in Lisbon. Diabetes Research and Clinical Practice, 95(2), 153–161. https://doi.org/10.1016/j.diabres.2011.10.001

[17] Hamid, M. H., Arbab, A. H., and Yousef, B. A. (2020). Bacteriological profile and antibiotic susceptibility of diabetic foot infections at Ribat University Hospital: A retrospective study from Sudan. Journal of Diabetes and Metabolic Disorders, 19, 1397–1406. https://doi.org/10.1007/s40200-020-00660-8

[18] Al Benwan, K., Al Mulla, A., and Rotimi, V. O. (2012). A study of the microbiology of diabetic foot infections in a teaching hospital in Kuwait. Journal of Infection and Public Health, 5(1), 1–8. https://doi.org/10.1016/j.jiph.2011.07.004

[19] Goh, T. C., Bajuri, M. Y., Nadarajah, S. C., Abdul Rashid, A. H., Baharuddin, S., and Zamri, K. S. (2020). Clinical and bacteriological profile of diabetic foot infections in a tertiary care centre. Journal of Foot and Ankle Research, 13, 36. https://doi.org/10.1186/s13047-020-00406-y

[20] Rennie, R. P., Jones, R. N., and Mutnick, A. H. (2003). Occurrence and antimicrobial susceptibility patterns of pathogens isolated from skin and soft tissue infections: Report from the SENTRY Antimicrobial Surveillance Program (United States and Canada). Diagnostic Microbiology and Infectious Disease, 45(4), 287–293. https://doi.org/10.1016/S0732-8893(02)00543-6

[21] Bertrand, X., Costa, Y., and Pina, P. (2005). Surveillance of antimicrobial resistance of bacteria isolated from bloodstream infections: Data of the French national observatory for epidemiology of bacterial resistance to antibiotics (ONERBA), 1998–2003. Médecine et Maladies Infectieuses, 35(6), 329–334. https://doi.org/10.1016/j.medmal.2005.05.002

[22] Labani, Y. (2016). *Bacteriological profile and frequency of antibiotic resistance in diabetic foot infection* (Thesis No. 22, Faculty of Medicine and Pharmacy, Marrakech).