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Microbiological characteristics and antimicrobial resistance patterns of catheter-associated urinary tract infections in patients of the therapeutic department

Abstract

Background: Catheter-associated urinary tract infections (CAUTIs) represent one of the most common healthcare-associated infections, often caused by multidrug-resistant organisms. This study aimed to investigate the etiological profile, antimicrobial resistance patterns, and risk factors of CAUTIs among patients admitted to a therapeutic department.

Methods: A retrospective-prospective comparative observational study was conducted at the Grodno University Clinic from January 2024 to September 2025. A total of 200 patients with confirmed urinary tract infections were included: 100 with urinary catheters and 100 without. Microbiological cultures and antibiotic susceptibility testing were performed according to CLSI (2023) standards. Statistical analyses included χ^2 and t-tests; logistic regression was applied to identify independent risk factors for multidrug-resistant infection. A p-value of <0.05 was considered statistically significant.

Results: *Escherichia coli* was the predominant pathogen in both groups, but its frequency was significantly lower among catheterized patients (34% vs. 56%, p=0.003). *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* were more common in catheterized individuals. Catheter-associated isolates showed higher resistance to ampicillin (82% vs. 58%), ciprofloxacin (46% vs. 28%), and a greater prevalence of ESBL-producing strains (38% vs. 20%). Multidrug resistance was detected in 48% of isolates from catheterized patients compared with 27% in non-catheterized cases (p<0.01). Catheterization and prior antibiotic exposure were independent predictors of MDR infection.

Conclusion: Urinary catheterization substantially increases the risk of infection by multidrug-resistant and ESBL-producing pathogens. Continuous surveillance, rational antibiotic use, and minimizing catheter duration are essential to reduce the burden of CAUTIs and improve patient outcomes.

Keywords: catheter-associated urinary tract infection, antimicrobial resistance, *escherichia coli*, *klebsiella pneumoniae*, extended-spectrum β-lactamase, multidrug resistance, infection prevention, hospital epidemiology

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Abbreviations: AMR, antimicrobial resistance; CAUTI, catheter-associated urinary tract infection; CFU, colony-forming units; CI, confidence interval; CKD, chronic kidney disease; CLSI, clinical and laboratory standards institute; ESBL, extended-spectrum β-lactamase; HAI, healthcare-associated infection; ICU, intensive care unit; IQR, interquartile range; IUC, indwelling urinary catheter; MDR, multidrug resistance/multidrug-resistant; MRSA, methicillin-resistant *staphylococcus aureus*; NHSN, national healthcare safety network; OR, odds ratio; SD, standard deviation; UTI, urinary tract infection

Introduction

Catheter-associated urinary tract infections (CAUTIs) represent one of the most frequent types of healthcare-associated infections globally, imposing significant morbidity, prolonged hospital stays, and increased healthcare costs. According to the 2023 National Healthcare Safety Network (NHSN) report, more than 17,000 CAUTI events were recorded across U.S. acute care hospitals over 23 million catheter device-days.[1] Globally, CAUTI incidence densities range from approximately 1.3 per 1,000 catheter-days in high-income settings to over 8.8 per 1,000 catheter-days in low- and middle-income countries, underscoring a substantial and unevenly distributed global burden.[2] These infections occur when an indwelling urinary catheter disrupts the natural defense mechanisms of the urinary tract, providing a surface for microbial adherence and biofilm formation. The risk is especially high in hospitalized patients, particularly those with prolonged catheterization, advanced age, comorbidities such as diabetes, or impaired mobility.[3,4]

While *Escherichia coli* remains the dominant pathogen in many urinary tract infections, in CAUTIs the microbial spectrum is broader and often includes *Klebsiella pneumoniae, Pseudomonas aeruginosa, Enterococcus* spp., and *Candida* in some settings.[5,6] The presence of biofilms on catheter surfaces further complicates treatment, as biofilm-embedded organisms display increased tolerance to antibiotics and to host immune responses.[6,7]

Antibiotic resistance among uropathogens involved in CAUTIs is an escalating threat. Extended-spectrum β-lactamase (ESBL) producing Gram-negative bacteria, fluoroquinolone resistance, and multidrug-resistant (MDR) organisms are reported increasingly in recent studies, limiting empirical therapy options and leading to therapeutic failures.[8] Additionally, risk factors such as duration of catheterization, patient age, comorbidities (e.g., diabetes mellitus,

renal insufficiency), and lack of strict catheter care protocols are associated with higher incidence and worse outcomes of CAUTIs.[7,9]

In regional or smaller hospital settings, including many therapeutic wards, resources for infection surveillance, timely microbiological diagnostics, and antimicrobial stewardship may be constrained. Consequently, local data on pathogen distribution and resistance profiles are essential to guide empirical treatment and to inform prevention efforts. Despite a growing number of studies, there remain gaps in understanding how CAUTIs manifest in non-surgical therapeutic wards (as opposed to ICU or urology wards), particularly in settings outside major academic centers.

Therefore, **this study aimed** to characterize the microbiological features of CAUTIs among patients in the therapeutic department of the hospital. Specifically, we compared the etiological agents and antibiotic susceptibility profiles of isolates from catheterized versus non-catheterized patients. We also sought to identify local risk factors associated with CAUTI occurrence, with the aim of supporting more precise empirical therapy, optimizing antimicrobial use, and strengthening infection prevention strategies in similar settings.

Materials and methods

This observational comparative study was conducted at the Grodno University Clinic, a regional hospital that provides multidisciplinary medical services to adult patients. The investigation covered the period from January 2024 to September 2025. The study employed a combined retrospective-prospective design. The retrospective component involved the extraction of demographic and clinical data (including comorbidities, prior antibiotic exposure, and catheter duration) from existing medical records of patients hospitalized during the study period. The prospective component involved the active, standardized collection of urine samples, performance of microbiological cultures, and antimicrobial susceptibility testing conducted in real time according to a pre-defined protocol throughout the study period.

A total of 200 adult patients diagnosed with urinary tract infection (UTI) were included in the study. No formal sample size calculation was performed; rather, the study employed a consecutive sampling strategy, enrolling all eligible patients who met the inclusion criteria during the study period from January 2024 to September 2025. The final sample of 200 patients (100 catheterized and 100 non-catheterized) represents the complete eligible population identified at the Grodno University Clinic therapeutic department over this timeframe. They were divided into two groups according to the presence or absence of an indwelling urinary catheter.

a) Group I (catheterized patients) consisted of 100 individuals who had a urinary catheter in place for more than 48 hours prior to the development of UTI symptoms.

b) Group II (non-catheterized patients) included 100 individuals with UTI but without any history of catheterization during the current hospital stay.

Patients with asymptomatic bacteriuria, polymicrobial contamination without clinical signs of infection, or incomplete medical records were excluded from the analysis. The inclusion criteria were: (1) clinical evidence of UTI (fever, dysuria, suprapubic tenderness, or flank pain), (2) laboratory confirmation through positive urine culture, and (3) age ≥18 years.

Urine samples were collected under aseptic conditions, in accordance with international microbiological standards. For catheterized patients, samples were obtained directly from the catheter sampling port after disinfection with 70% alcohol and clamping for 15-30 minutes to avoid contamination from the drainage bag. In non-catheterized patients, midstream clean-catch specimens were used. All samples were promptly transported to the hospital's microbiology laboratory within one hour of collection.

Microbiological analysis was performed using standard culture techniques. Samples were inoculated onto blood agar and MacConkey agar plates and incubated at 37°C for 18-24 hours. Isolated colonies were identified by conventional biochemical tests (oxidase, catalase, indole, urease, citrate, and triple sugar iron reactions) and confirmed, when available, by automated systems such as VITEK-2 (bioMérieux, France). Only isolates showing $\geq 10^5$ colony-forming units (CFU)/mL were considered clinically significant.

Antimicrobial susceptibility testing was carried out by the Kirby-Bauer disk diffusion method according to the Clinical and Laboratory Standards Institute (CLSI, 2023) guidelines. The antibiotics tested included ampicillin, amoxicillin-clavulanate, cefotaxime, ceftriaxone, ceftazidime, cefepime, ciprofloxacin, gentamicin, amikacin, nitrofurantoin, trimethoprim-sulfamethoxazole, and carbapenems (imipenem, meropenem). Extended-spectrum β-lactamase (ESBL) production among Gram-negative isolates was screened using the double-disk synergy test. Methicillin resistance in *Staphylococcus aureus* was detected using cefoxitin disks.

Demographic and clinical data (age, sex, duration of hospitalization, comorbidities, and duration of catheterization) were extracted from medical records. All data were anonymized before analysis.

Statistical processing was conducted using Statistica version 10.0. Quantitative variables were expressed as mean ± standard deviation (SD), and categorical variables as absolute numbers and percentages. Comparisons between groups were made using the χ^2 test or Fisher's exact test for categorical variables, and Student's t-test for continuous data. A p-value of <0.05 was considered statistically significant.

Results

A total of 200 patients with microbiologically confirmed urinary tract infection (UTI) were analyzed, including 100 catheterized (Group I) and 100 non-catheterized (Group II) individuals. The mean age of catheterized patients was 66.4±12.8 years, significantly higher than that of the control group (58.9±14.7 years, p=0.001). Females constituted 55% of Group I and 62% of Group II (p>0.05).

Common comorbidities included arterial hypertension (62%), type 2 diabetes mellitus (29%), chronic kidney disease stage ≥3 (18%), and prior antibiotic use within 30 days (34%). Diabetes was more frequent among catheterized patients (36% vs. 22%, p=0.03). The mean duration of hospital stay was longer in the catheterized group (12.1±6.3 days) compared with non-catheterized patients (7.9±4.1 days), p<0.001. In Group I, the median duration of catheterization prior to UTI diagnosis was 7 days (interquartile range, IQR 4–12 days).

Bacteriological profile of isolates

A total of 236 bacterial isolates were recovered from the urine samples (mean: 1.18 isolates per patient). Gram-negative bacteria were predominant in both groups, but more frequent among catheterized patients (82% vs. 68%, p=0.02).

The leading uropathogen in both groups was *Escherichia coli*, although its relative frequency was considerably lower in catheterized patients (34% vs. 56%, p=0.003). In contrast, *Klebsiella pneumoniae*

(22% vs. 14%) and *Pseudomonas aeruginosa* (12% vs. 4%) were more common in the catheterized cohort (Table 1, Figure 1).

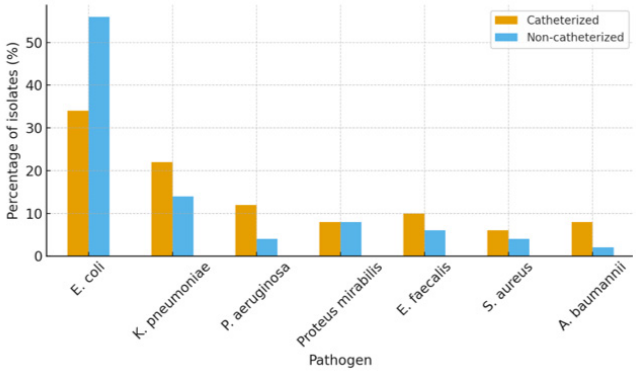

Figure 1 Distribution of major uropathogens in catheterized and non-catheterized patients.

Table 1 Distribution of bacterial pathogens in catheterized and non-catheterized patients

Bacterial species	Catheterized (n=100)	Non-catheterized (n=100)	p-value
Escherichia coli	34 (34%)	56 (56%)	0.003
Klebsiella pneumoniae	22 (22%)	14 (14%)	0.12
Pseudomonas aeruginosa	12 (12%)	4 (4%)	0.04
Proteus mirabilis	8 (8%)	8 (8%)	1.00
Enterococcus faecalis	10 (10%)	6 (6%)	0.31
Staphylococcus aureus	6 (6%)	4 (4%)	0.52
Acinetobacter baumannii	8 (8%)	2 (2%)	0.05

Bar chart showing the relative frequency of the most common bacterial species isolated from urine cultures. Escherichia coli predominated in both groups but was markedly more frequent among non-catheterized patients, while Klebsiella pneumoniae and Pseudomonas aeruginosa were more prevalent in catheterized individuals. This shift toward non-fermenting Gram-negative bacilli in the catheterized group is clinically significant, as these organisms are intrinsically more resistant to antibiotics, form biofilms on catheter surfaces, and are associated with higher rates of treatment failure and prolonged hospitalization.

Antimicrobial susceptibility patterns

Catheter-associated isolates exhibited significantly higher resistance rates across multiple antibiotic classes. *E. coli* strains from catheterized patients demonstrated resistance to ampicillin in 82% of cases versus 58% in the non-catheterized group (p=0.01) and resistance to ciprofloxacin in 46% versus 28%, respectively (p=0.03) (Table 2, Figure 2).

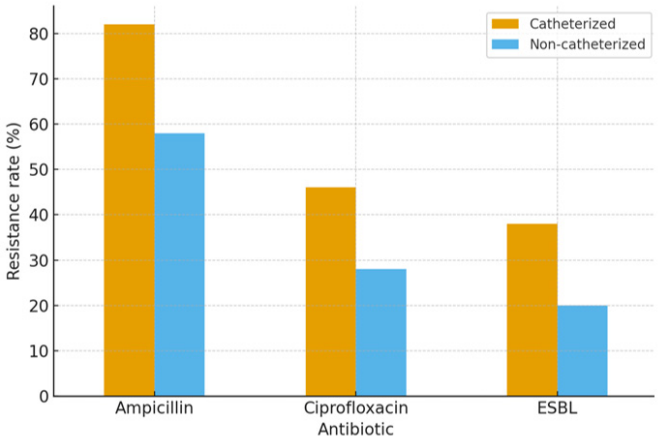

Figure 2 Comparative antibiotic resistance of *E. coli* isolates.

Table 2 Antimicrobial resistance rates among major Gram-negative pathogens

Pathogen	Antibiotic	Catheterized (%)	Non-catheterized (%)	p-value
E. coli	Ampicillin	82	58	0.01
E. coli	Ciprofloxacin	46	28	0.03
E. coli	ESBL-positive	38	20	0.02
K. pneumoniae	Ceftriaxone	64	42	0.04
K. pneumoniae	Carbapenem-resistant	8	0	0.02
P. aeruginosa	Ceftazidime	50	28	0.05
P. aeruginosa	Carbapenem-resistant	10	0	0.03

Comparison of resistance rates to key antibiotics (ampicillin, ciprofloxacin, and ESBL production) among E. coli isolates. Catheter-associated isolates exhibited significantly higher resistance rates across all tested antibiotics. The high prevalence of ESBL-producing strains (38%) among catheterized patients is of particular clinical concern, as ESBL production renders entire classes of beta-lactam antibiotics ineffective and substantially limits empirical treatment options, often necessitating carbapenem therapy and increasing the risk of therapeutic failure in the absence of timely susceptibility data.

Extended-spectrum β-lactamase (ESBL) production was found in 38% of E. coli and 44% of *K. pneumoniae* isolates among catheterized patients, compared with 20% and 26% among their non-catheterized counterparts (p<0.05). Overall, ESBL-producing strains accounted for 38% of all catheter-associated isolates versus 20% among non-catheterized cases (Figure 3). Carbapenem resistance was detected only in catheter-associated infections: 8% of K. pneumoniae and 10% of P. aeruginosa isolates showed resistance to meropenem or imipenem.

Pie charts showing the proportion of extended-spectrum β-lactamase (ESBL) producers among all isolates. The percentage of ESBL-positive strains was substantially higher among catheterized patients (38%) than among non-catheterized ones (20%). This nearly two-fold difference underscores the role of urinary catheters as a selective pressure for resistant organisms, likely driven by biofilm formation and repeated antibiotic exposure. The high ESBL burden in the catheterized group has direct implications for empirical antibiotic protocols, suggesting that standard beta-lactam regimens may be inadequate as first-line therapy in this patient population.

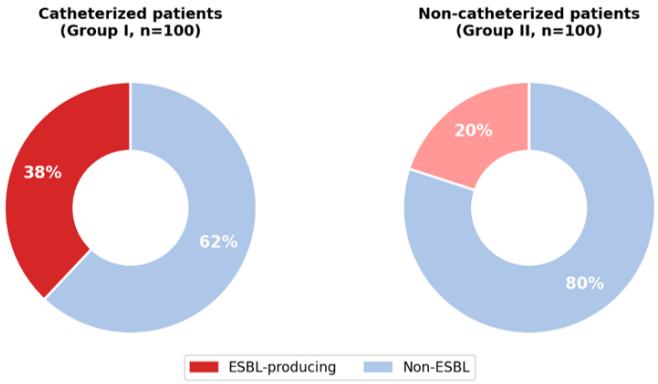

Figure 3 Proportion of ESBL-producing isolates in both study groups.

The overall prevalence of multidrug resistance (defined as resistance to three or more antibiotic classes) was 48% among catheter-associated isolates, compared with 27% in non-catheter-associated cases ($p<0.01$) (Figure 4).

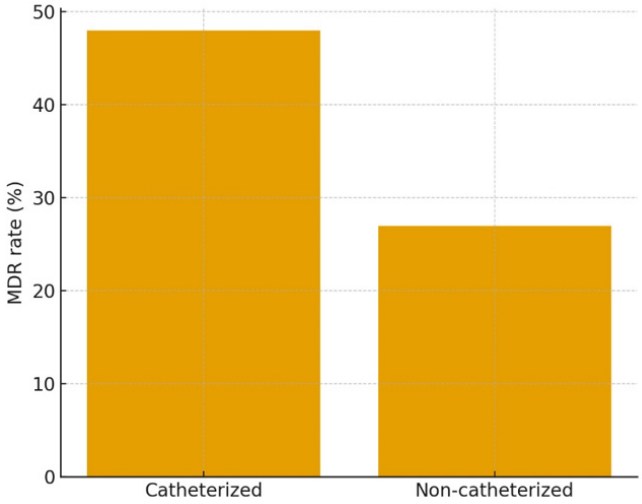

Figure 4 Prevalence of multidrug resistance (MDR) among isolates.

Bar chart comparing the overall rate of multidrug-resistant isolates, defined as resistance to three or more antibiotic classes. MDR strains were observed in 48% of isolates from catheterized patients and 27% from non-catheterized individuals. The finding that nearly half of all catheter-associated isolates exhibit multidrug resistance is alarming from a public health perspective. It highlights the urgent need for active local AMR surveillance, strict catheter stewardship to minimize unnecessary device use, and the development of institution-specific empirical treatment guidelines that reflect the true local resistance landscape rather than relying on national or international benchmarks alone.

Logistic regression analysis identified catheterization (OR=2.6; 95% CI: 1.4-4.7; p=0.002), prolonged hospitalization (>10 days) (OR=2.1; p=0.01), and prior antibiotic exposure (OR=2.8; p<0.001) as independent risk factors for multidrug-resistant infection.

Additional microbiological observations

Biofilm-associated organisms and non-fermenting Gram-negatives were disproportionately recovered from catheter tips and catheter-port aspirates compared with voided specimens. Among patients harboring Pseudomonas or *Acinetobacter* spp., repeat cultures after catheter replacement showed clearance in 60% of cases. Clearance was achieved when device removal was combined with targeted antimicrobial therapy, suggesting that the catheter itself serves as a major microbial reservoir.

In summary, catheterized patients in our therapeutic department were older, had more comorbidities (notably diabetes), and experienced longer hospital stays compared with the control group. The microbiological profile of CAUTIs differed from non-catheterized UTIs by a higher frequency of non-fermenting Gram-negative *bacilli*, *enterococci*, *Candida* spp., and a higher prevalence of ESBL production and multidrug resistance. Catheterization and recent antibiotic exposure independently predicted isolation of MDR organisms. These results highlight the need for targeted catheter care, stewardship of empirical antimicrobial therapy, and local surveillance to inform treatment guidelines.

Discussion

Our study provides a comprehensive analysis of urinary tract infections in patients with and without urinary catheters, focusing on pathogen distribution, antimicrobial resistance (AMR) patterns, and risk factors. The findings reveal significant differences between the two groups, aligning with and extending the results of several recent studies.

The observed association between urinary catheterization and MDR pathogen isolation can be explained by several interrelated mechanisms. First, the catheter surface provides a scaffold for biofilm formation, within which bacteria are embedded in a protective extracellular matrix that markedly reduces antibiotic penetration and confers tolerance to concentrations far exceeding the minimum inhibitory concentration. Second, the prolonged presence of a foreign body triggers a local inflammatory response that paradoxically impairs mucosal immunity, facilitating colonization by opportunistic and resistant organisms. Third, catheterized patients frequently receive repeated or prolonged courses of antibiotics – both therapeutic and prophylactic – which exert strong selective pressure favoring the emergence and persistence of MDR strains. Fourth, the urinary drainage system creates a semi-closed environment that can accumulate resistant organisms over time, particularly when catheter replacement is delayed. Together, these mechanisms explain why catheterized patients in our cohort had an MDR prevalence of 48%, compared with 27% among non-catheterized individuals, and why catheterization emerged as an independent predictor of MDR infection on logistic regression (OR=2.6; 95% CI: 1.4–4.7; p=0.002).

In our cohort, *Escherichia coli* was the predominant uropathogen in both catheterized and non-catheterized patients. However, the relative frequency of E. coli was notably higher in the non-catheterized group, whereas Klebsiella pneumoniae and *Pseudomonas aeruginosa* were more prevalent in the catheterized group. This observation is consistent with the findings of Jha et al.,[3] who identified *E. coli, K. pneumoniae*, and *Candida* species as major CAUTI pathogens, with substantial multidrug resistance among Gram-negative bacteria.

Similarly, Tegegne et al.,[10] emphasized the role of bacterial biofilm formation in catheter-associated UTIs, which may contribute to the increased prevalence of resistant pathogens in this population.

Our study observed higher resistance rates to ampicillin, ciprofloxacin, and ESBL production among catheter-associated *E. coli* isolates. These findings align with the research of Miftode et al.,[11] who reported lower susceptibility rates to carbapenems in patients with urinary catheters, highlighting the escalating issue of AMR in this population.

Furthermore, Obaid et al.,[12] documented patterns of antibiotic resistance and risk factors for CAUTI-related infections in ICUs in Saudi Arabian hospitals, underscoring the global nature of this concern.

MDR pathogens were significantly more prevalent among device-bearing patients in our cohort. This finding is corroborated by the work of Onorato et al.,[13] who reported a 39.1% prevalence of MDR pathogens in patients admitted to emergency departments for UTIs.

Additionally, Ghali et al.,[14] identified prolonged hospitalization, advanced age, hospitalization method, and history of neurogenic bladder as significant risk factors for healthcare-associated UTIs, emphasizing the need for targeted infection control measures.

The high burden of resistant and MDR pathogens among device-associated cases underscores the need for rigorous infection control. Key measures include regular AMR surveillance, antimicrobial stewardship, and timely catheter removal – all of which are essential to reduce CAUTI-related morbidity and improve patient outcomes.

Conclusion

The present study showed that urinary catheterization significantly increases the risk of UTIs and changes their microbial profile. *Escherichia coli* predominated in non-catheterized patients, while *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* were more common in catheterized cases.

Catheter-associated isolates showed markedly higher resistance to beta-lactams, fluoroquinolones, and aminoglycosides, with frequent detection of ESBL-producing strains. These findings correspond to international data reporting similar resistance trends and pathogen distributions in CAUTIs.

Overall, urinary catheterization remains a key preventable risk factor for multidrug-resistant infections. Rational antibiotic use, strict aseptic techniques, and minimizing catheter duration are essential to reduce infection rates and improve patient outcomes.

Limitations

Several limitations of this study should be acknowledged. First, the study was conducted at a single tertiary-care center in Grodno, Belarus, which may limit the generalizability of findings to other healthcare settings or geographic regions with different resistance profiles. Second, despite employing a consecutive sampling strategy, the relatively small sample size of 200 patients may not fully capture the breadth of pathogen diversity, particularly for less-common organisms such as *Candida* spp. and *Acinetobacter baumannii*, which were present in small numbers. Third, the retrospective component of the study relied on medical record data, introducing the possibility of incomplete documentation of comorbidities, catheter care practices, or prior antibiotic exposure. Fourth, molecular typing of isolates and whole-genome sequencing were not performed; therefore, clonal transmission events and plasmid-mediated resistance mechanisms could not be evaluated. Fifth, the study did not include long-term follow-up data on patient outcomes, recurrence rates, or mortality attributable to CAUTI. Future multicenter studies with larger sample sizes and molecular epidemiological tools are warranted to confirm and extend these findings.

Ethical approval

This study was conducted in accordance with the principles of the Declaration of Helsinki. Formal ethical committee approval was not required for this study, as it involved the analysis of routinely collected, anonymized clinical and microbiological data obtained in the course of standard patient care. No experimental interventions were performed, and no individually identifiable patient information was used or disclosed. All data were fully anonymized prior to analysis to ensure patient confidentiality.

Acknowledgments

None

Conflicts of interest

The authors declare that there are no conflicts of interest.

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