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ORIGINAL ARTICLE

Reducing catheter urinary tract infection risk through biofilm prevention: evidence-based strategies for urinary catheter management

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ABSTRACT

Background and Objectives: Catheter-associated urinary tract infections (CAUTIs) are common healthcare-associated infections mainly caused by biofilm formation on urinary catheters. This study aimed to provide evidence-based catheter management strategies to reduce CAUTI risk through biofilm prevention.
Materials and Methods: This prospective observational study included 109 adult patients undergoing urinary catheterization between September 2017 and January 2018. Urine samples were collected after catheter insertion and before catheter removal. Bacteriuria was screened using flow cytometry and confirmed by urine culture. Removed catheters were cultured to assess biofilm formation, while isolates were tested for biofilm-forming ability using Congo Red Agar (CRA).
Results: The mean catheterization duration was 5.6 ± 2.1 days, and most patients were catheterized for ≥5 days. Bacteriuria was significantly associated with catheterization ($p = 0.029$). Antibiotic use reduced bacteriuria incidence ($p < 0.001$) but did not significantly reduce biofilm formation (73.4%, $p > 0.05$). CRA-positive isolates showed 1.5-fold greater biofilm-forming potential. Female sex, early bacteriuria, and catheterization >5 days were associated with biofilm formation.
Conclusion: Urinary catheterization promotes biofilm and increases CAUTI risk. Although antibiotics reduced bacteriuria, they showed limited efficacy against biofilms. Early bacteriuria screening, routine monitoring, biofilm prevention, and limiting catheter duration may help reduce CAUTI incidence.

Keywords: Anti-bacterial agents; Biofilms; Bacteriuria; Treatment; Urinary tract infections

INTRODUCTION

Catheter-associated urinary tract infections (CAUTIs) remain one of the most common healthcare-associated infections worldwide and represent a significant burden on healthcare systems (1, 2). The widespread use of urinary catheters in hospitalized patients, particularly in intensive care units and long-term care settings, substantially increases the risk of urinary tract infections (3, 4). CAUTIs are associated with prolonged hospital stays, increased healthcare costs, and higher morbidity, emphasizing the need for effective preventive strategies (5).

The pathogenesis of CAUTIs is strongly linked to the formation of microbial biofilms on the surface of urinary catheters (5, 6). Biofilms consist of complex

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microbial communities embedded in an extracellular matrix that adheres firmly to catheter materials (7-9). Once established, these biofilms act as persistent reservoirs of infection, facilitating bacterial survival and colonization within the urinary tract (5). Importantly, bacteria producing biofilm exhibit significantly increased resistance to antimicrobial agents and host immune responses, leading to recurrent and difficult to treat infections (10-12).

The increasing concern surrounding biofilm-mediated infections highlights the urgency of developing effective preventive strategies for CAUTIs. Unlike planktonic bacteria, biofilm-producing microorganisms can survive under hostile environmental conditions and exhibit significantly enhanced antimicrobial resistance, making conventional treatment approaches less effective (10-12). Furthermore, because biofilm formation is closely linked to catheter use, CAUTIs are considered among the most preventable healthcare-associated infections through appropriate catheter management and early intervention (4, 13). Preventing biofilm development on urinary catheters therefore represents a critical strategy to reduce infection risk, limit antimicrobial resistance, and improve patient outcomes.

Several factors influence the development of CAUTIs, among which patient-related and device-related factors play a crucial role. Sex-based differences have been consistently recognized as a significant determinant of susceptibility, largely due to anatomical differences that influence the risk of infection. In this study, positive biomass results were observed more frequently among female patients than among male patients (4, 13, 14). In addition, the duration of catheterization is one of the strongest predictors of CAUTI occurrence, as prolonged catheter use provides sufficient time for microbial adhesion, biofilm maturation, and subsequent infection. Each additional day of catheterization further increases the risk of infection (4, 15).

Given the central role of biofilm formation and modifiable risk factors such as catheter duration, this study was conducted to provide evidence-based catheter management strategies aimed at reducing the incidence and risk of CAUTIs. Preventable CAUTIs impose a substantial economic burden on healthcare systems, with estimated annual costs ranging from 115 million to 1.82 billion USD (16). These findings underscore the critical importance of implementing evidence-based catheter management protocols to limit biofilm development, decrease CAUTI incidence, and ultimately reduce the associated healthcare burden. Therefore, this study aimed to provide evidence-based catheter management strategies for reducing the risk of CAUTIs through the prevention of biofilm formation on urinary catheters.

MATERIALS AND METHODS

Patients and samples collection. This prospective observational study involved 109 adult patients undergoing urinary catheterization between September 2017 and January 2018 at a private hospital in Tangerang, Banten, Indonesia. Eligible participants included hospitalized adults aged more than 18 years who underwent urethral catheterization for longer than 48 hours. Patients were excluded if they had conditions such as hydronephrosis, pyelonephritis, pregnancy, malignancy, immune-compromised disorders, or a history of hypersensitivity to catheter materials.

Participants were also excluded when urinalysis or culture data were incomplete or when consent to participate was withdrawn. Clinical and demographic information, including age, sex, diabetes status, antibiotic therapy, duration of catheterization, and urinalysis findings, were collected from patients' medical records.

Following catheter removal, urine specimens were obtained for urinalysis and culture examination to identify bacteriuria. The distal 5 cm section of each removed catheter was aseptically excised and subsequently divided into five 1 cm segments. These catheter fragments were then immersed in sterile saline solution for further analysis.

Bacteriuria screening and urine culture. Bacteriuria screening was initially performed using flow cytometry–based urinalysis with the Sysmex UF-1000i. The reference range for bacterial count was 0.0–130.7/µL for female patients and 0.0–26.4/µL for male patients. Samples with bacterial counts exceeding these reference values were classified as bacteriuria-positive and were subsequently subjected to conventional urine culture.

For urine culture, 100 µL of each urine specimen was inoculated onto blood agar and MacConkey agar plates. The inoculum was evenly distributed across the agar surface using a sterile disposable loop. All culture plates were incubated aerobically at 35-37°C

for 18-24 hours. Following incubation, bacterial colonies were quantified and identified using standard microbiological methods. A significant positive urine culture was defined as bacterial growth of $\geq 10^2$ colony-forming units (CFU)/mL.

Biofilm formation test. Removed urinary catheters were processed to assess biofilm formation. The distal 5-cm segment of each catheter was aseptically excised and sectioned into smaller pieces, which were then immersed in sterile saline solution. Samples collected from the catheter surface were cultured on blood agar and MacConkey agar plates then incubated aerobically at 35-37°C for 18-24 hours to isolate bacteria associated with catheter-related biofilms.

Bacterial isolates recovered from both urine cultures and catheter specimens were subsequently evaluated for biofilm-forming capacity using the Congo Red Agar (CRA) method. Each isolate was inoculated onto CRA plates and incubated aerobically at 35-37°C for 24-48 hours. Biofilm production was determined based on colony morphology and color changes observed on the culture medium. Black colonies with a dry, crystalline appearance were interpreted as biofilm-positive, whereas red or pink colonies were classified as non–biofilm producers. Biofilm formation on the catheter surface was further assessed through quantitative measurement of biofilm biomass. The detailed procedure for biofilm biomass quantification has been described previously (4).

RESULTS

The study population comprised patients aged 18 to 88 years, with a predominance of female participants. The mean duration of catheterization was 5.6 ± 2.1 days, with the majority of patients having catheters in place for five days or more. Diabetes mellitus was present in 22% of the cohort, while 68.8% received antibiotic therapy during catheterization (Table 1). The antibiotics most commonly used included empiric therapies such as meropenem and third-generation cephalosporins.

Bacteriuria was identified in 34% (n = 37) of patients immediately after catheter insertion, and in 20% (n = 22) at the time of catheter removal. A significant association was observed between catheter placement and bacteriuria (p = 0.029) (Table 2).

Antibiotic use was significantly associated with a reduced risk of post-catheterization bacteriuria (p < 0.001; OR = 0.130; 95% CI: 0.046–0.366). Patients who received antibiotics demonstrated a lower incidence of bacteriuria compared with those who did not receive antibiotics (9.3% vs. 44.1%) (Table 3).

Table 1. Patient characteristic

Characteristic	Amount (%)
Gender	
Female	42 (38.5)
Male	67 (61.5) Mean:
Duration of catherization	5.6 ± 2.1
< 5 days	43 (39.4)
≥ 5 days	66 (60.6)
Diabetes mellitus history	24 (22)
Antibiotic use during catheterization	75 (68.8)

Furthermore, analysis of bacterial isolates demonstrated a significant association between biofilm-producing capacity and biofilm formation on catheter surfaces. Isolates identified as biofilm producers exhibited a significantly higher frequency of catheter-associated biofilm formation than non–biofilm-producing isolates (Table 4).

DISCUSSION

The results of this study indicate that urinary catheter insertion is a risk factor for the development of bacteriuria. This condition is likely attributable to disruption of the urinary tract's natural defense mechanisms caused by the presence of an indwelling catheter. Catheter insertion provides a direct pathway for microorganisms from the periurethral area to enter the bladder, as well as a surface that facilitates bacterial adhesion and colonization. Moreover, both the external and internal surfaces of the catheter may serve as routes for bacterial invasion, either through contamination of the catheter tip by distal urethral flora during insertion or through bacterial migration along the catheter surface, even when a closed drainage system is properly maintained (16, 17).

Additional contributing factors include suboptimal aseptic technique during catheter insertion, contamination of the catheter lumen, and inadequate catheter care (18). These findings emphasize that catheter insertion itself is an important trigger for the development of bacteriuria, even during short-term catheter use (Table 2).

Table 2. The association of bacteriuria (flow cytometry) during catheter insertion and post-catheterization.

Bacteriuria at the Time of Catheter Insertion	Post-Catheterization* Bacteriuria			p value
	Positive (%)	Negative (%)	Amount (%)	
Positive	9 (8.3)	28 (25.7)	37 (34)	
Negative	13 (11.7)	59 (54.3)	72 (66)	0.029
Amount	22 (20)	87 (80)	109 (100)	

*Bacteriuria at post-catheterization (urine sample collected immediately before catheter removal)

Table 3. Association between post-catheterization Bacteriuria detected by flow cytometry and antibiotic use.

Post-Catheterization Bacteriuria	Antibiotic used n (%)		p value
	Yes	No	
Positive	7 (9.3)	15 (44.1)	
Negative	68 (90.7)	19 (55.9)	< 0,001
Amount	75 (100)	34 (100)	

Table 4. Relationship between the biofilm-producer bacteria and the biofilm formation.

No	Bacteria	Biofilm formation (n %)		p-value
		Positive	Negative	
1	Biofilm-producing bacteria	40 (95)	2 (5)	
2	Non Biofilm-producing bacteria	40 (59.7)	27 (40)	<0.001
	Amount	80	29	

The incidence of post-catheterization bacteriuria decreased to 20%, compared with 37% observed at the time of urinary catheter insertion. This reduction may be associated with the characteristics of the study population, particularly because the majority of patients (68.8%) received antibiotic therapy during catheterization (Table 1). This finding is consistent with the statistically significant inverse association identified between antibiotic use and post-catheterization bacteriuria ($p < 0.001$; OR = 0.130; 95% CI: 0.046-0.366), with bacteriuria occurring less frequently among patients receiving antibiotics than among those without antibiotic exposure (9.3% vs. 44.1%, respectively) (Table 3). One possible explanation is that the empiric antibiotic therapy administered, particularly meropenem, has demonstrated high clinical efficacy in the treatment of urinary tract infections in previous studies (19). In addition, the lower incidence of bacteriuria among patients receiving antibiotics may be related to the predominance of bacteria in the planktonic state, which allows greater antibiotic penetration into bacterial cells and facilitates disruption of essential cellular processes (20).

Despite its association with reduced bacteriuria, antibiotic administration in our previous study did not significantly decrease catheter-associated biofilm formation, which remained detectable in 73.4% of cases ($p > 0.05$) (4). This finding suggests that conventional antibiotic therapy has limited effectiveness against microorganisms embedded within biofilms. These results are consistent with previous studies reporting that biofilm formation enhances microbial resistance to antimicrobial agents and contributes to infection persistence and recurrence (21-23).

In line with these findings, conversion of bacteriuria results on urinalysis from positive at catheter insertion to negative at catheter removal was not always accompanied by negative urine culture results. Notably, 36% (10 subjects) with positive bacteriuria were found to have positive urine cultures, predominantly caused by *Candida* spp., which are not responsive to antibiotic therapy. This observation is consistent with the findings of Zwet et al., who reported that the UF-1000i Sysmex analyzer has limited sensitivity for detecting fungal organisms, potentially leading to underestimation of fungal involvement in catheter-associated infections (24). Another possible explanation is the presence of false-positive results in the initial bacteriuria assessment shortly after catheterization, as the UF-1000i flow cytometry analyzer is characterized by a low false-negative rate (0%) but a relatively high false-positive rate (35%). This performance profile suggests that flow cytometry can be effectively used to reduce unnecessary follow-up urine cultures when bacteriuria results are negative, while positive findings should be interpreted cau-

tiously and confirmed with culture (24, 25).

Isolates with positive Congo Red Agar (CRA) results were 1.5 times more likely to form biofilms than CRA-negative isolates. Biofilm formation was observed in 95% of CRA-positive isolates, compared with 59.7% of CRA-negative isolates (Table 4). Statistical analysis further demonstrated a significant association between bacterial biofilm-forming capacity and biofilm formation on urinary catheters ($p < 0.001$). However, a negative CRA result does not completely exclude the potential for biofilm formation. Previous studies involving *Staphylococcus epidermidis* strains classified as non–biofilm producers showed that these isolates remained capable of forming biofilms through alternative mechanisms, including increased cell surface hydrophobicity, which plays a key role in initial bacterial adhesion and colonization (26). In addition, trypsin exposure has been reported to induce biofilm formation in *S. epidermidis* strains previously identified as non–biofilm producers (27). These findings indicate that CRA-negative isolates may retain the capacity to develop biofilms under specific environmental conditions. Therefore, the CRA method should be considered a screening approach rather than a definitive method for excluding biofilm-forming ability.

Furthermore, our previous study demonstrated that catheterization for more than five days was significantly associated with increased biofilm formation ($p = 0.004$). Additional factors associated with biofilm development included female sex, bacteriuria at the time of catheter insertion, and prolonged catheterization. Biofilm formation was detected as early as day 3 (62%), whereas bacterial dispersal from established biofilms—which may subsequently contribute to bacteriuria—was generally observed around day 5 (4). These findings underscore the importance of minimizing catheter duration whenever clinically feasible.

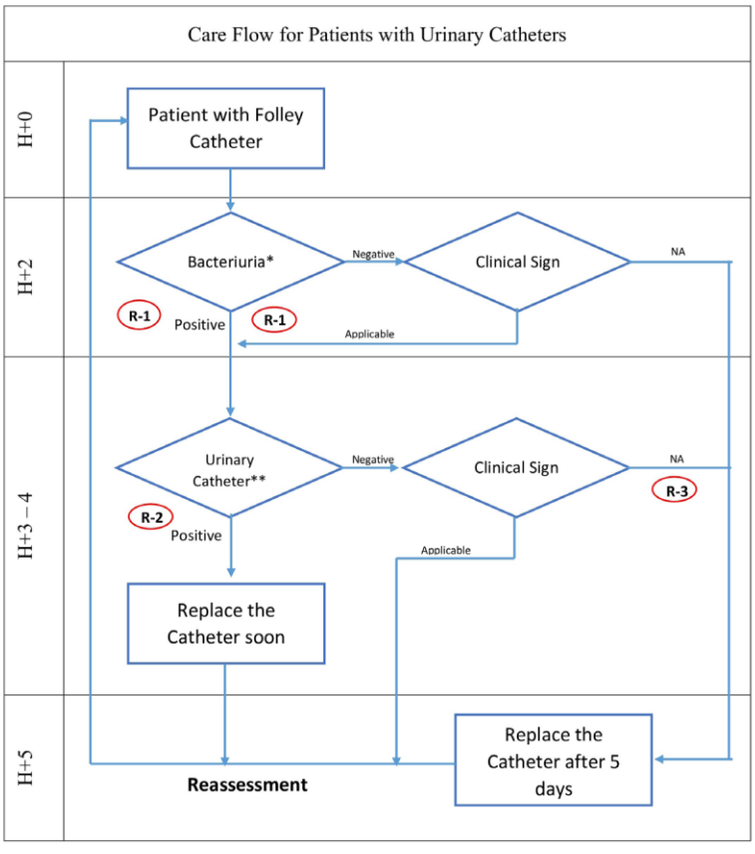
Based on these findings, routine monitoring of patients with indwelling urinary catheters for more than 48 hours may be beneficial, including in asymptomatic individuals. Flow cytometry–based urinalysis may serve as an early screening method for bacteriuria and a preliminary indicator of potential catheter-associated biofilm formation (Fig. 1). When bacteriuria is detected, urine culture should be performed to identify causative organisms and assess their biofilm-forming capacity, thereby facilitating earlier detection of asymptomatic catheter-associated urinary tract infection (CAUTI) (Fig. 1).

Previous studies have identified Gram-negative Enterobacteriaceae as the predominant microorganisms isolated from both urine and urinary catheter cultures, particularly *Escherichia coli* (28.1%) and *Klebsiella pneumoniae* (15.9%), along with *Candida* spp. (17.8%). These microorganisms are well-established causative agents of catheter-associated urinary tract infection (CAUTI) and commonly originate from the endogenous perineal microbiota. Their ability to adhere to catheter surfaces and form biofilms has been widely documented and contributes to microbial persistence and ongoing infection (28).

From a therapeutic perspective, determination of the minimum biofilm inhibitory concentration (MBIC) may be valuable in guiding antibiotic management for catheter-associated infections. This approach may support more appropriate antibiotic selection, improve treatment effectiveness, and reduce the risk of therapeutic failure related to biofilm-associated infections. Previous studies have reported that most *Escherichia coli* isolates remain highly susceptible to meropenem, amoxicillin–clavulanic acid, and fosfomycin. However, among these antibiotics, fosfomycin was the only agent shown to exhibit significant antibiofilm activity. Differences in resistance phenotypes between urinary and catheter-derived isolates have also been reported, although no significant differences were observed in minimum inhibitory concentration (MIC; $p = 0.522$) or minimum biofilm inhibitory concentration (MBIC; $p = 0.523$) values (12).

In this previous study, amoxicillin–clavulanic acid and fosfomycin may be considered potential therapeutic options for infections caused by planktonic bacteria, whereas fosfomycin appears to demonstrate greater effectiveness against biofilm-associated microorganisms (4, 12). These findings suggest that treatment strategies targeting biofilm formation may improve therapeutic outcomes in the management of catheter-associated urinary tract infection (CAUTI).

This study has several limitations. Bacterial species identification and antimicrobial susceptibility testing were not performed, as the microbiological characteristics and susceptibility profiles of pathogens associated with catheter-associated urinary tract infection (CAUTI) have been extensively described in previous studies. The primary objective of the present study was to evaluate biofilm formation and catheter-related factors as evidence-based ap-



H+0 : Day of catheter insertion; H+2: Two days after catheter insertion; H+3 – 4: Three to four days after catheter insertion; H+5: Five days after catheter insertion; R-1: Empirical antibiotic recommendation; R-2: Definitive antibiotic recommendation; R-3: recommendation to stop theraphy; *: through flow cytometry test; **through identification, sensitivity test, antibiofilm test (CRA) and MBIC.

Fig. 1. Care flow for patients with urinary catheter.

proaches for reducing the risk of CAUTI.

In conclusion, biofilm formation plays a critical role in the pathogenesis and persistence of CAUTI. Although antibiotic therapy may reduce bacteriuria, its effectiveness against catheter-associated biofilms remains limited. Therefore, routine assessment of biofilm formation and appropriate catheter management, including minimizing catheter duration and early monitoring for bacteriuria, are important strategies to reduce CAUTI risk and improve clinical outcomes.

Future studies should investigate the expression of virulence-associated genes to further clarify their contribution to biofilm formation. In addition, multicenter studies are needed to validate the proposed management algorithm across a broader hospital setting. The incidence of CAUTI should be used as the primary outcome to evaluate the effectiveness of these interventions.

CONCLUSION

Urinary catheterization remains a major risk factor for bacteriuria and catheter-associated urinary tract infection (CAUTI), primarily by facilitating microbial biofilm formation. Although antibiotic therapy may reduce bacteriuria, its effectiveness against catheter-associated biofilms remains limited. Prolonged catheterization and the biofilm-forming capacity of bacterial isolates were significantly associated with biofilm development on urinary catheters, highlighting the important role of biofilm in CAUTI persistence and antimicrobial resistance.

These findings emphasize the importance of evidence-based catheter management, including early bacteriuria screening, routine monitoring of catheterized patients, and strategies to prevent biofilm formation. Reducing catheter duration and improving early detection of biofilm-associated infection may

contribute to lowering CAUTI incidence and improving clinical outcomes.

REFERENCES

1. Werneburg GT. Catheter-associated urinary tract infections: Current challenges and future prospects. *Res Rep Urol* 2022;14: 109-133.
2. Centers for Disease Control and Prevention. Catheter-associated Urinary Tract Infection (CAUTI) Basics [Internet]. [cited 2026 Jan 10]. Available from: https://www.cdc.gov/uti/about/cauti-basics.html
3. Sleziak J, Błażejewska M, Duszyńska W. Catheter-associated urinary tract infections in the intensive care unit during and after the COVID-19 pandemic. *BMC Infect Dis* 2025; 25: 595.
4. Gunardi WD, Karuniawati A, Umbas R, Bardosono S, Lydia A, Soebandrio A, et al. Biofilm-Producing Bacteria and Risk Factors (Gender and Duration of Catheterization) Characterized as Catheter-Associated Biofilm Formation. *Int J Microbiol* 2021; 2021: 8869275.
5. Tegegne DT, Abbott IJ, Poźniak B. Catheter-Associated Urinary Tract Infections: Understanding the Interplay Between Bacterial Biofilm and Antimicrobial Resistance. *Int J Mol Sci* 2025; 26: 9193.
6. Trautner BW, Darouiche RO. Role of biofilm in catheter-associated urinary tract infection. *Am J Infect Control* 2004; 32: 177-183.
7. Gunardi WD, Timotius KH, Natasha A, Evriarti PR. Biofilm Targeting Strategy in the Eradication of Burkholderia Infections: A Mini-Review. *Open Microbiol J* 2021; 15: 51-57.
8. Wang G, Wang X, Sun L, Gao Y, Niu X, Wang H. Novel Inhibitor Discovery of *Staphylococcus aureus* Sortase B and the Mechanism Confirmation via Molecular Modeling. *Molecules* 2018; 23: 977.
9. Karygianni L, Ren Z, Koo H, Thurnheer T. Biofilm Matrixome: Extracellular Components in Structured Microbial Communities. *Trends Microbiol* 2020; 28: 668-681.
10. Sahoo K, Meshram S. Biofilm Formation in Chronic Infections: A Comprehensive Review of Pathogenesis, Clinical Implications, and Novel Therapeutic Approaches. *Cureus* 2024; 16(10): e70629.
11. Mendhe S, Badge A, Ugemuge S, Chandi D. Impact of Biofilms on Chronic Infections and Medical Challenges. *Cureus* 2023; 15(11): e48204.
12. Gunardi WD, Dharmawan A, Layanto N. Antibiotic effectiveness on biofilm-producing *Escherichia coli* isolated from catheterized patients. *J Med Sci (Berkala Ilmu Kedokteran)* 2022; 54: 211-221.
13. Letica-Kriegel AS, Salmasian H, Vawdrey DK, Youngerman BE, Green RA, Furuya EY, et al. Identifying the risk factors for catheter-associated urinary tract infections: a large cross-sectional study of six hospitals. *BMJ Open* 2019; 9(2): e022137.
14. Perdana MA, Wahyuni DD, Yunita R. Characteristics and susceptibility pattern of catheter-associated urinary tract infections (CAUTI) bacteria in Indonesia: A study in a national reference hospital of Sumatra region 2020–2021. *Narra J* 2023; 3(3): e436.
15. Ghali H, Saad OKB, Bhiri S, Balhi S, Azouzi F, Maatouk A, et al. Epidemiology and risk factors of healthcare-associated urinary tract infections: a prospective study in a Tunisian tertiary hospital. *Sci Rep* 2025; 15: 29948.
16. Skok K, Bele U, Pintar Š, Peršin Z, Kuzmič K, Bračič M, et al. Urinary catheters: state of the art and future perspectives - a narrative review. *Mater Today Bio* 2025; 34: 102225.
17. Rubi H, Mudey G, Kunjalwar R. Catheter-Associated Urinary Tract Infection (CAUTI). *Cureus* 2022; 14(10): e30385.
18. Chakraverty R, Kundu AK (2024). Catheter-Associated Urinary Tract Infections (CAUTI): Prevalence and Management. In: *Hospital-Acquired Infections in Intensive Care Unit and Their Management*. Singapore: Springer Nature Singapore, pp. 55-66.
19. Sivanandy P, Manirajan P, Wen Qi O, Teng Khai O, Chun Wei O, Wei Ying N, et al. A systematic review of efficacy and safety of newer drugs approved from 2016 to 2023 for the treatment of complicated urinary tract infections. *Ann Med* 2024; 56: 2403724.
20. Martins KB, Ferreira AM, Pereira VC, Pinheiro L, de Oliveira A, da Cunha MLRS. In vitro Effects of Antimicrobial Agents on Planktonic and Biofilm Forms of *Staphylococcus saprophyticus* Isolated From Patients With Urinary Tract Infections. *Front Microbiol* 2019; 10: 40.
21. Abebe GM. The role of bacterial biofilm in antibiotic resistance and food contamination. *Int J Microbiol* 2020; 2020: 1705814.
22. Sharif S, Yadav AK. Bacterial biofilm and its role in antibiotic resistance. *The Microbe* 2025; 7: 100356.
23. Li N, Shi R, Sun Y, Chen Q. Effective interventions to prevent catheter-associated urinary tract infections: a systematic review. *Rev Inst Med Trop Sao Paulo* 2025; 67: e61.
24. Van Der Zwet WC, Hessels J, Canbolat F, Deckers MM. Evaluation of the Sysmex UF-1000i® urine flow cytometer in the diagnostic work-up of suspected urinary tract infection in a Dutch general hospital. *Clin Chem Lab Med* 2010; 48: 1765-1771.
25. Le Z, Li F, Fei C, Ye A, Xie X, Zhang J. Performance of the Sysmex UF-1000i urine analyser in the rapid di-

agnosis of urinary tract infections in hospitalized patients. *J Infect Chemother* 2016; 22: 377-382.
26. Fernández-Calderón MC, Fernández-Babiano I, Navarro-Pérez ML, Pazos-Pacheco C, Calvo-Cano A. Biofilm formation and role of other pathogenic factors in the virulence of *Staphylococcus epidermidis* clinical isolates. *Front Cell Infect Microbiol* 2025; 15: 1630341.
27. Martínez-García S, Ortega-Peña S, De Haro-Cruz MJ, Aguilera-Arreola MG, Alcántar-Curiel MD, Betanzos-Cabrera G, et al. Non-biofilm-forming commensal *Staphylococcus epidermidis* isolates produce biofilm in the presence of trypsin. *Microbiologyopen* 2019; 8(10): e906.
28. Wang J, Zhang Y, Xu D, Shao W, Lu Y. Evaluation of the Sysmex UF-1000i for the diagnosis of urinary tract infection. *Am J Clin Pathol* 2010; 133: 577-582.