

## COMPREHENSIVE ANALYSIS OF CATHETER-ASSOCIATED URINARY TRACT INFECTIONS: RISK FACTORS, MICROBIAL DYNAMICS, AND ANTIMICROBIAL CHALLENGES IN A TERTIARY CARE SETTING

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Received: 16 December 2023, Revised and Accepted: 29 January 2024

### ABSTRACT

**Introduction:** Indwelling urinary catheters are frequently employed in medical procedures; yet, they pose a considerable risk, with catheter-associated urinary tract infections (CAUTIs) being a global healthcare challenge. CAUTIs account for 30–40% of nosocomial infections, contributing to heightened morbidity and mortality.

**Objective:** Our objectives included investigating CAUTI incidence, exploring factors contributing to UTI risk, examining the correlation between bacteriuria and symptomatic CAUTI, and recording microbiological profiles and antibiotic sensitivities for insights into microbial dynamics and treatment strategies.

**Method:** We aimed to assess patient and catheter-related factors influencing urinary tract infections (UTIs) in 105 catheterized patients.

**Results:** Among the studied cohort, with an average age of 47.73 years, various catheter sizes were employed, and post-operative catheterization was the predominant indication. Microbial presence in urine samples was detected in 31.4% of cases, with a 21% prevalence of symptomatic UTIs. Diabetes mellitus showed a significant association with increased UTI occurrences ( $p=0.019$ ). Notably, catheterization outside the operating theater (OT) and prolonged catheterization duration were significantly associated with increased infection rates ( $p=0.000$  and  $p=0.003$ , respectively). Despite antibiotic treatment, *Escherichia coli* remained the most prevalent organism causing infection (17.1%), and antibiotic resistance trends were observed, highlighting the challenges of antimicrobial stewardship.

**Conclusion:** The study emphasizes the importance of preventive measures, such as reducing catheterization duration and meticulous diabetes management, to mitigate the burden of CAUTIs. In conclusion, this study provides valuable insights into the prevalence, risk factors, and microbial dynamics of CAUTIs, urging a shift toward proactive prevention strategies and judicious antibiotic use to enhance patient outcomes and alleviate the strain on health-care resources.

**Keywords:** UTI, CAUTI, CAABU, CATHETER, SEPSIS, asymptomatic bacteriuria, biofilm.

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### INTRODUCTION

The utilization of indwelling urinary catheters is integral to various medical procedures [1]. Catheter-associated urinary tract infection (CAUTI) stands as the most prevalent nosocomial infection globally, constituting approximately 30–40% of all institutionally acquired infections [2]. Moreover, UTIs contribute to over 9.5% of infections reported by acute care hospitals [3]. The Centers for Disease Control (CDC) define CAUTI as any urinary tract infection (UTI) occurring in a patient with an indwelling catheter in place at the time of or within 48 h before the onset of infection [1]. CAUTI can manifest in various forms, ranging from asymptomatic bacteremic UTIs to symptomatic UTIs, potentially leading to genitourinary complications such as pyelonephritis, cystitis, prostatitis, epididymo-orchitis, and systemic complications such as vertebral osteomyelitis, septic arthritis, endocarditis, endophthalmitis, and meningitis. Notably, 3% of all catheterized patients develop bacteremia [4]. According to the CDC, CAUTI increases morbidity and mortality by 2.8-fold, and the length of hospitalization is extended by 1–3 days [1]. While antibiotics serve as the cornerstone for CAUTI treatment, the catheter's abiotic surface is prone to biofilm formation. In addition, antibiotic treatment can lead to collateral damage and alterations in the vaginal and gut microbiota [5].

The global concern over antibiotic resistance is evident in declarations made by the CDC in 2013, stating that the human race has entered a “post-antibiotic era,” and the World Health Organization’s warning in 2014 about the dire nature of the antibiotic resistance phenomenon [6,7].

In light of these challenges, this study was conducted to assess patient and catheter-related factors contributing to UTIs in catheterized patients. The aim is to mitigate the burden of hospital-acquired infections at Karnataka Institute of Medical Sciences (KIMS), Hubballi, a tertiary care hospital.

### Aims and objectives

The objectives of the study are as follows:

1. Investigate CAUTI incidence in Urology Department admissions at KIMS, Hubballi
2. Examine factors contributing to UTI risk in catheterized patients
3. Explore bacteriuria’s correlation with symptomatic CAUTI for insights into infection manifestation
4. Record microbiological profiles and antibiotic sensitivities in catheter-associated UTIs for microbial insights and treatment strategies.

**METHODS**

In this 2022–2023 prospective study, 105 patients underwent Foley catheterization at the hospital or within 24 h of arrival. Inclusion criteria focused on ensuring a comprehensive understanding of CAUTI, while exclusion criteria ruled out pregnant women, those allergic to latex or silicone, patients with urethral catheters >48 h, subjects with pre-existing positive urine cultures, and those with suprapubic catheters. Urine cultures were conducted at catheterization, 48 hours later, and during symptomatic episodes. Meticulously recorded clinical data included age, gender, systemic diseases, recent surgery, and catheterization indication. Details of catheter size and placement were documented. Quantitative organism analysis at 24 and 48 h, along with antibiotic susceptibility testing, aimed to offer insights into CAUTI dynamics and contribute to preventive and management strategies.

**RESULTS**

In this study, encompassing 105 participants, the average age of the subjects was 47.73 years (standard deviation: 16.53 years), ranging from 17 to 88 years. The cohort exhibited a diverse age distribution, with 24.76% falling within the 31–40 year age group and 21.9% in the 51–60 year age bracket.

The gender distribution revealed that 67% of the participants were male, while 33% were female. Various catheter sizes, including 14 Fr, 16 Fr, 18 Fr, and 20 Fr, were utilized, with 14 Fr being the most frequently employed (48.57% in 51 cases).

Among catheterized individuals, 20% experienced fever, 13.3% reported suprapubic pain, 2.9% had loin pain, and 24.8% presented with lower urinary tract symptoms (LUTS). Notably, some patients experienced a combination of these symptoms.

Microbial presence in urine samples from catheterized patients was detected in 31.4% of cases. Specifically, 21% of the catheterized participants (22 out of 105) exhibited the coexistence of microorganisms in urine samples alongside symptoms such as fever, suprapubic, or loin pain. Consequently, the prevalence of symptomatic UTIs in catheterized patients within this study reached 21%.

These findings provide valuable insights into the demographic characteristics, catheter usage patterns, and prevalence of symptoms and microbial presence among catheterized individuals, contributing to our understanding of UTIs in this cohort.

Catheterization indications encompassed various factors, including output monitoring in 17 subjects (16.19%), acute urinary retention in 21 individuals (20%), urinary incontinence in 3 participants (3%), and post-operative cases in 64 patients (60.95%). Notably, post-operative catheterization emerged as the most prevalent indication in this study.

In the analysis exploring factors linked to UTIs, the presence of diabetes mellitus exhibited a statistically significant association (p=0.019) with heightened UTI occurrences. Conversely, no significant associations were identified between UTIs and gender (p=0.214), hypertension

(HTN) (p=0.198), tuberculosis (TB) (p=0.967), or chronic obstructive pulmonary disease (COPD) (p=0.967).

The analysis of various factors related to UTI revealed significant associations. Specifically, the place of catheterization outside the operating theater (OT) exhibited a notably significant association (p=0.000) with increased infection rates. However, no significant associations were found between infection and other monitored variables, including output monitoring (p=0.084), acute urinary retention (p=0.558), urinary incontinence (p=0.592), and post-operative status (p=0.345). In addition, catheter size did not show a significant association with UTI (p=0.436).

The distribution of cases without detectable organisms in urine was higher in the 2–4 days catheterization group, comprising 62 cases, compared to the >4 days catheterization group, which had 10 cases. Conversely, the presence of organisms in urine was more prevalent in the >4 days catheterization group, with 13 cases, compared to the 2–4 days catheterization group, which had 20 cases. This observed association indicates a significant relationship between the duration of catheterization and the presence of organisms in urine, including bacteriuria and CAUTIs (p=0.003).

Another Chi-square analysis was conducted to explore the association between the duration of catheterization and the presence or absence of fever. The results revealed no statistically significant association between these variables (p=0.345).

The presence of symptoms, such as fever, suprapubic or loin pain, and irritative LUTS, exhibited a statistically significant association (p=0.012) with the growth of organisms in the analysis of variables related to organisms in the sample. Specifically, cases where these symptoms were present showed a higher incidence of organism growth compared to cases where these symptoms were absent.

Out of the 105 patients, 11 individuals (10.47%) had microbial growth in their urine, with *Escherichia coli* being the most common organism. Interestingly, these patients did not exhibit symptoms such as fever, flank pain, or LUTS. Among the study subjects, the most prevalent organism causing infection was *E. coli* (17.1%, 18 cases), followed by *Klebsiella* (7.6%, 8 cases).

Among the antibiotics studied, piperacillin and tazobactam showed sensitivity in 20 cases (62.5%) and resistance in 12 cases (37.5%) against the microorganisms present in the urine samples. Similarly, amikacin exhibited sensitivity in 19 cases (59.4%) and resistance in 13 cases (40.6%). These findings suggest that piperacillin and tazobactam, as well as amikacin, displayed higher sensitivity compared to ciprofloxacin, which showed sensitivity in 10 cases (31.3%) and resistance in 22 cases (68.8%). Furthermore, nitrofurantoin exhibited sensitivity in 11 cases (34.4%) and resistance in 2 cases (6.3%) against the microorganisms found in the urine samples.

**DISCUSSION**

Indwelling urinary catheters have become a routine aspect of care for many urological patients. However, like any medical intervention, the

Microorganism (n)	Antibiotic							
	Pipzo (Piperacillin and Tazobactam)		Amikacin		Ciprofloxacin		Nitrofurantoin	
	Resistant	Sensitive	Resistant	Sensitive	Resistant	Sensitive	Resistant	Sensitive
<i>Escherichia Coli</i> (18)	4	14	4	14	12	6	11	7
<i>Klebsiella</i> (8)	3	5	4	4	5	3	5	3
<i>Proteus</i> (2)	0	2	1	1	2	0	1	1
<i>Pseudomonas</i> (3)	2	1	1	2	2	1	3	0
Staph Species (2)	2	0	2	0	2	0	2	0
Total	12	20	13	19	22	10	21	11

advantages of catheter use must be carefully considered in light of potential adverse effects [8].

In this study, the criteria for defining CAUTI followed the CDC guidelines, focusing on bacteriuria accompanied by symptoms (symptomatic UTI). Among 105 catheterized patients, 22 cases (21%) exhibited the presence of microorganisms in urine samples alongside symptoms such as fever, suprapubic, or loin pain, resulting in a prevalence of symptomatic UTI (CAUTI) of 21%. In contrast, Domingo *et al.* and Danchavijitr *et al.* reported higher CAUTI incidences of 51.4% and 73.3%, respectively [9,10]. Discrepancies in CAUTI rates across studies can be attributed to variations in criteria used for CAUTI definition.

Asymptomatic bacteriuria (CAABU) was observed in 10.47% of patients in our study. Cope *et al.* reported 164 CAABU episodes among 268 studied patients [11]. There is a pressing need for improved recognition of CAABU, distinguishing it from CAUTI, to curb unnecessary antibiotic use in hospitalized patients. In our study, antibiotics were administered to CAUTI patients.

Various studies, including those by Platt *et al.*, Shapiro *et al.* and Johnson *et al.*, have identified risk factors significantly associated with CAUTI [12-14]. Factors such as prolonged catheterization, gender, diabetes, advancing age, and catheter care violations were found to increase the risk. Our study similarly found a statistically significant association ( $p=0.019$ ) between the presence of diabetes mellitus and increased UTI occurrences. Diabetics consistently showed an elevated risk of CAUTI across various studies, potentially attributed to increased colonization of microorganisms in the perineum and urine, as well as altered host immunity, though further investigation is needed [15,16].

No significant associations were observed between UTI and gender ( $p=0.214$ ), HTN ( $p=0.198$ ), TB ( $p=0.967$ ), or COPD ( $p=0.967$ ) in our study. However, the place of catheterization outside the sterile confines of the operating room exhibited a notably significant association ( $p=0.000$ ) with increased infection rates. Furthermore, the duration of catheterization emerged as a significant risk factor ( $p=0.003$ ), indicating a relationship between prolonged catheterization and bacteriuria/CAUTI. This aligns with findings from a comprehensive study by Maki and Tambyah, indicating that longer catheterization durations increase the likelihood of ascending infections (OR 5.2).

Catheter size did not show a significant association with UTI ( $p=0.436$ ), consistent with literature findings.

The predominant organisms causing infection in our study were *E. coli* (18 cases, 17.1%) and *Klebsiella* (8 cases, 7.6%), mirroring findings in other studies. We sought to evaluate the sensitivity and resistance of uropathogens to commonly available antibiotics at KIMS, Hubballi. However, the results indicated resistance trends, with ciprofloxacin and nitrofurantoin showing limited sensitivity, potentially linked to the overarching issue of over-treatment of CAABU with antibiotics, use of over-the-counter drugs, and the universal occurrence of biofilm formation on catheter surfaces in the urinary tract.

Biofilms, structured communities of microorganisms within a self-developed polymeric matrix adherent to a surface, contribute to bacteriuria becoming prevalent in long-term catheterization cases. Antimicrobial exposure in patients with indwelling urinary catheters often leads to antimicrobial-resistant bacteria isolation, with *E. coli* strains persisting due to the presence of Type 1 pili and the Tamm-Horsfall protein. Catheter care violations emerged as a significant risk factor in our study, consistent with findings from studies by Maki and Tambyah [17] and Tenke *et al.* [18].

In conclusion, the study sheds light on the prevalence and risk factors associated with CAUTI, emphasizing the importance of judicious antibiotic use and catheter care practices in managing UTIs among catheterized patients.

## CONCLUSION

The presence of an indwelling catheter poses an elevated risk of infection to the urinary system, with the majority of patients developing CAUTI within seven days of catheterization. The increased and inappropriate use of antibiotics further heightens the risk of infections from antibiotic-resistant organisms. Instead of focusing on treating CAUTI after it occurs, the primary objective for every appropriately catheterized patient should be CAUTI prevention. This is particularly crucial in developing nations like ours, where understanding the significant risk factors contributing to CAUTI development can alleviate additional strain on the healthcare system.

The study's findings underscore key preventive measures, including reducing the duration of catheterization, vigilant management of diabetes, and adopting hygienic precautions during indwelling catheter insertion and maintenance, all contributing to CAUTI avoidance.

Consistent adherence to the CDC's definitions of CAUTI is imperative to ensure comparable results for future research. It is essential to assess numerous recommendations and research endeavors aimed at preventing UTIs associated with catheter use. Future studies should explore the role of antibiotic prophylaxis, the instillation of antibiotics and other agents in drainage bags, and the use of various perineal care agents.

Ultimately, the focus should be on identifying, disseminating, and implementing effective methods to prevent or reduce the occurrence of UTIs related to catheter use. This approach is critical for enhancing patient outcomes and minimizing the burden on health-care resources.

## ACKNOWLEDGMENTS

The authors thank the patients who participated in the study. Dr. Ravikumar Jadhav, Associate Professor, Dept of Urology, Kims, Hubballi. Dr. Thakappa N.g, Assistant Professor, Dept of Urology, Kims, Hubballi. Dr. Raviraj Raykar, Professor Andhead, Dept of Urology, Kims, Hubballi. Dr. Manjuprasad G.b, Associate Professor, Dept of Urology, Kims, Hubballi. Dr. Sampathkumar, Assistant Professor, Dept of Urology, Kims, Hubballi. Dr. Shivaratna Mahadik, Urology Resident, Dept of Urology, Kims, Hubballi, Dr. Jaideep Ratkal, Professor, Dept of Urology, Kims, Hubball.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval for conducting the study was obtained from the KIMS, Hubballi. Written informed consent was obtained from the patient for her participation in the study.

## CONSENT FOR PUBLICATION

The patient's informed consent has been acquired for the publication of the case details, clinical images, and relevant medical information. All efforts have been made to ensure patient confidentiality, and any identifying information has been appropriately anonymized.

## COMPETING INTERESTS

The authors declare no competing interests, financial or otherwise, that could have influenced the content or interpretation of this case study.

## FUNDING

This research received no specific grant from any funding agency, commercial entity, or not-for-profit organization. The study was conducted solely as part of the authors' academic and clinical activities.

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