

# Catheter-Associated Urinary Tract Infections: A Comprehensive Review of Prevention and Management Approaches for Nurses

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## ABSTRACT

Catheter-associated urinary tract infections (CAUTIs) are a prevalent healthcare-associated illness, accounting for a significant proportion of hospital-acquired

infections. This review explores the epidemiology, mechanism of infection, risk factors, prevention strategies, and guidelines related to CAUTIs. The incidence of CAUTIs varies across regions, with higher rates reported in developing countries and ICUs. The mechanism of infection involves biofilm formation on catheter surfaces and the introduction of bacteria through various pathways. Risk factors include age, gender, duration of catheterization, diabetes mellitus, and caregiver-related factors. Prevention strategies encompass avoiding unnecessary catheterization, selecting appropriate catheters, implementing proper insertion and maintenance techniques, and establishing surveillance programs. Evidence-based guidelines and bundled approaches have demonstrated effectiveness in reducing CAUTI rates. Implementing customized infection prevention and control programs with senior management leadership is crucial for successful CAUTI reduction. Further research on catheter surface modifications and antimicrobial coatings may provide additional strategies for preventing biofilm formation and reducing the incidence of CAUTIs in healthcare settings.

**KEYWORDS:** Nurses, Catheter Associated Urinary Tract Infection, Cautis.

## 1. Introduction

Catheter-associated urinary tract infections (CAUTIs) remain one of the most prevalent healthcare-associated illnesses globally, accounting for approximately 40% of hospital-acquired infections and 80% of all nosocomial urinary tract infections (UTIs). CAUTIs, a type of nosocomial infection, are defined as infections acquired during a hospital stay, typically manifesting within 48 hours of hospital admission (Nicolle, 2014). Microbial colonization generally occurs between 5 to 7 days after catheter insertion, often linked to the development of a bacterial biofilm, which is considered a primary source of CAUTIs. According to the Centers for Disease Control and Prevention (CDC), symptomatic CAUTI is characterized by significant bacteriuria (105 cfu/mL) and at least two signs or symptoms of acute UTI (such as fever, suprapubic tenderness, costovertebral angle pain or tenderness, urinary urgency, urinary frequency, or dysuria) in patients with an indwelling urethral catheter in place for more than two days (Garner et al., 1988).

A urinary tract infection (UTI) affects components of the urinary system, including the urethra, bladder, ureters, and kidneys. In 2015, acute care facilities reported 62,700 cases of UTIs, making them the fifth most frequent type of healthcare-associated infection, responsible for over 9.5% of hospital-acquired infections (Magill et al., 2018).

Urinary tract infections associated with urinary catheters have significant clinical and economic consequences. These infections can contribute to excess mortality rates, even after considering underlying factors such as illness severity and comorbidities. Hospital-onset bloodstream infections originating from a urinary source have a case fatality rate of 32.8% (Chenoweth & Saint, 2013).

The urinary system plays a crucial role in eliminating liquid waste from the body, comprising two primary sections: the upper tract, containing the kidneys and ureters, and the lower tract, which includes the bladder and urethra. The lower tract stores

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urine in the bladder, which is then expelled from the body through the urethra [5]. Problems with the lower urinary tract, such as nerve damage or muscle weakening resulting in incontinence, prostate enlargement, or urethral stricture causing urinary retention, may necessitate the use of a urinary catheter in hospitalized patients, especially those critically ill (Chapple, 2011; Feneley et al., 2015).

## Epidemiology

Asia is projected to experience an even more significant impact from CAUTI (Chuang & Tambyah, 2021). In regions with microbiological monitoring, CAUTIs in developing countries have also been associated with higher rates of antibiotic resistance (Ling et al., 2015). The extensive use of urinary catheters in healthcare settings highlights the substantial effect and importance of CAUTI within global healthcare, particularly across Asia (Umscheid et al., 2011).

In South-East Asia, the Eastern Mediterranean, Europe, the Western Pacific, and North and South America, the incidence of catheter-associated urinary tract infection per 1,000 catheter days was recorded as 15.71, 9.86, 8.99, 6.90, and 5.70, respectively, with an average rate of 8.50 (Peng et al., 2018). Among ICU patients, those with ICU-acquired symptomatic CAUTI had a significantly higher ICU mortality rate and a notably shorter ICU length of stay compared to patients with ward-acquired symptomatic CAUTI (Ding et al., 2019).

The overall infection rates for CAUTI, central line-associated bloodstream infection (CLABSI), and ventilator-associated pneumonia (VAP) within ICUs at seven hospitals in the International Infection Control Consortium (INICC), spanning seven cities in India, were reported as 1.41 per 1,000 catheter days, 7.92 per 1,000 catheter days, and 10.46 per 1,000 ventilator days, respectively. In this study conducted in the ICUs of northern Indian hospitals, VAP rates were comparatively lower, while CLABSI rates were notably higher. These rates (CAUTI: 8.9/1,000 catheter days, CLABSI: 12.8/1,000 catheter days, and VAP: 24/1,000 ventilator days) were comparable to those reported by 55 ICUs in other developing nations (Datta et al., 2014).

## Mechanism of infection

Urine contains high levels of urea (400 mM), which serves as a substrate for urease. This enzyme hydrolyses urea into CO<sub>2</sub> and NH<sub>3</sub>, aiding in the elimination of excess nitrogen. The ammonia released in this process raises the pH of the urine, leading to the precipitation of typically soluble polyvalent anions and cations, which can result in urolithiasis. Crystals may form both on and inside the catheter lumen, obstructing urine flow and necessitating catheter removal and replacement (Finer & Landau, 2004). Patients with short-term catheterization are less prone to develop this condition, as the bacteria involved are rarely isolated after the initial colonization of the catheterized urinary tract and tend to persist longer in the urinary tract (Tambyah et al., 1999). Most catheter-associated UTIs are endogenous, originating from the patient's own intestinal flora, with the catheter itself increasing the risk of UTIs through various mechanisms.

Indwelling urinary catheters, which are inserted via the urethra into the bladder and connected to a collection system, often lead to infections. Each day a catheter remains in place, there is an approximately 5% increase in bacteriuria, which may be symptomatic or asymptomatic. In many cases, however, bacteriuria is asymptomatic and does not require treatment (Saint, Meddings, et al., 2009). Both the inner and outer surfaces of indwelling devices provide potential pathways for bacterial invasion. Even with careful maintenance of a closed system, bacteria can enter the bladder through the gap between the outer catheter and urethral mucosa (Warren, 1997). Bacteria may also enter the bladder by contaminating the catheter tip during insertion, via the distal urethral flora, or by migrating along the catheter's internal or external surfaces. This risk of bacteriuria is heightened in catheterized patients who have residual urine in the bladder (Barford et al., 2008). To initiate infection, bacteria must first attach to the epithelial cells of the urinary tract or the catheter's surface. Once biofilms form on these surfaces, the bacteria become more resistant to both the immune response and antimicrobial treatments.

Catheters can cause acute physical damage to the bladder epithelium and may also induce toxicity and inflammation. Bacterial-induced inflammation and epithelial damage may act synergistically to produce symptoms in the patient. Rather than being a simple slime layer, a biofilm is a dynamic structure comprising multiple bacterial species, their polysaccharide matrix, and residues from human fluids (D. B. W. Trautner & Darouiche, 2004). Biofilm formation on catheters begins with the development of a conditioning film on the device's surface. This conditioning layer may eventually conceal the original catheter surface, which may promote microbial adhesion even if the exposed catheter material itself would not typically support colonization (Choong & Whitfield, 2000).

### Risk Factors

For catheter-associated bacteriuria, defined as a positive culture showing 10<sup>5</sup> organisms/mL, various risk factors are recognized, including age, gender, physiologic condition at hospital admission, duration of catheterization, presence of diabetes mellitus, immune-compromised status, neurological disorders, and recent use of systemic antibiotics upon hospitalization (Tissot et al., 2001).

### Gender

Patients with additional active infection sites and females face a notably higher risk than males. Risk factors include malnutrition and renal insufficiency. While both genders are susceptible, infections were found to be slightly more frequent in men. This finding challenges the previous assumption that women's shorter urethra increases their susceptibility to infection (Girard et al., 2017).

### Age-Related

Among elderly hospital patients, who often have multiple chronic conditions, age has emerged as a significant risk factor for hospital-acquired UTIs, especially for those over 70 years of age. Although not previously regarded as critical, age is now acknowledged as a contributor to hospital-acquired UTIs in older adults (Girard et al., 2017).

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## Duration of Catheterization

The risk of CAUTI rises when catheters are inserted outside the operating room, when ureteral stents are present, or when catheters are used to monitor urine output. Studies consistently indicate that catheterization exceeding six days is the most significant modifiable risk factor, with nearly universal infection rates by the 30th day after catheter placement (Berman et al., 2014).

## In Patients with Diabetes Mellitus

Diabetes mellitus significantly increases the risk of CAUTIs, largely due to severe neuropathy, which can impair bladder emptying and encourage microbial growth. Additionally, insufficient insulin production or pancreatic beta-cell damage leads to elevated blood glucose levels. This results in glucosuria, a condition where glucose is present in urine, creating a favorable environment for bacterial growth and reducing leukocyte effectiveness in combating infection (Al-Rubeaan et al., 2013).

## Additional Patient-Related Factors

Other patient-related factors contributing to CAUTI risk include inadequate personal hygiene, fecal incontinence, and incomplete bladder emptying. Immobility in hospitalized patients also raises the likelihood of developing a UTI. Continuous catheter use and extended bed rest can exacerbate susceptibility to infection, as lying flat can disrupt normal urine flow, leading to stagnant urine. In an upright position, gravity assists urine movement from the renal pelvis to the bladder; however, while bedridden, the absence of gravity weakens the ureter's peristaltic motion, increasing infection risk (Berman et al., 2014).

## Caregiver-Related Factors

Risk factors related to caregivers include insufficient adherence to aseptic procedures during catheter insertion and maintenance. Additionally, catheters made of latex are associated with a higher CAUTI risk (Letica-Kriegel et al., 2019; Maki & Tambyah, 2001).

## Prevention

To design and evaluate effective prevention strategies, a thorough understanding of CAUTI etiology is essential (Kim et al., 2012). Preventative approaches often include replacing indwelling urinary catheters with alternative devices or implementing specific preventive practices. Options to consider include catheters with antimicrobial coatings, intermittent catheterization, suprapubic catheters, and condom catheters, all of which could serve as alternatives to indwelling urinary devices in the effort to reduce CAUTI incidence. However, evidence supporting these recommendations remains limited (B. W. Trautner et al., 2005). Catheterization options such as condom catheters and suprapubic catheters are selectively available, though their use is typically restricted. Condom catheters, while appropriate for male patients without bladder outlet obstruction, must be applied carefully to avoid complications like skin maceration, which has been associated with a higher likelihood of urinary tract infections. The introduction of closed catheter systems,

where the drainage bag and collection tube are connected, has been a crucial step in reducing CAUTI rates, and continued advancements in these drainage systems aim to further minimize infection risks (B. W. Trautner, 2010). Choosing the appropriate catheter size also plays a role in lowering CAUTI risk. Proper aseptic insertion techniques by healthcare and institutional staff, along with protocols to prevent contamination of collection bags after emptying, are essential measures to mitigate CAUTIs (Berman et al., 2014). Maintaining unobstructed urine flow is another highly effective strategy for CAUTI prevention (Dromerick & Edwards, 2003; Kim et al., 2012). Minimizing unnecessary catheter days has also proven to be beneficial in CAUTI reduction (P. Jain et al., 1995). Given that biofilm formation on urinary devices is integral to CAUTI pathogenesis, ongoing research is focused on modifying catheter surfaces to inhibit biofilm growth (Ren et al., 2001). This includes efforts to develop silicone-based catheters impregnated with antimicrobial or antiseptic agents to combat biofilm formation (Ha & Cho, 2006; Saint, Olmsted, et al., 2009).

In a related study, the Stensballe experiment compared nitrofurazone-impregnated silicone catheters to standard silicone catheters. Results indicated that the nitrofurazone group had a significantly delayed onset of bacteriuria and required less frequent adjustments or new antimicrobial treatments (Stensballe et al., 2007). Routine bacteriological surveillance in catheterized patients promotes early detection and intervention for urinary tract infections.

A “care bundle” is defined as a set of evidence-based interventions that, when applied individually, improve the patient’s healing process and outcomes, but when applied collectively, yield even better results. Typically, care bundles consist of three to five evidence-informed practices performed reliably to enhance care quality. Designed to prevent and manage various health conditions, preventive care bundles are an essential element of a multimodal approach focusing on high-impact interventions for CAUTI prevention (Mathur, 2018).

Healthcare providers and personnel involved in catheter care should receive regular in-service training, which emphasizes proper catheterization techniques and awareness of potential complications. Hands should be washed both before and after manipulating the catheter site or related equipment. Necessary supplies for insertion include gloves, drapes, sponges, an appropriate antiseptic solution for periurethral cleansing, and a single-use packet of lubricating jelly. To reduce cross-contamination risks, patients with indwelling catheters should not share rooms or be positioned in adjacent beds with patients without catheters (Conway & Larson, 2011; M. Jain et al., 2015). Approximately 35% of all healthcare-associated infections are urinary tract infections, of which 80% are linked to indwelling catheter use (Bailey & Scott’s Diagnostic Microbiology, 2015).

#### Avoidance of catheter use

To effectively prevent catheter-associated urinary tract infections (CAUTIs), the primary intervention is to avoid the use of indwelling urinary catheters whenever possible. Only specific, limited indications justify catheter use (Getliffe, 1994). These include close monitoring of hourly urine output in acutely ill patients; perioperative applications for certain surgeries, such as urological surgeries or those

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involving nearby genitourinary structures; during high-volume infusions or diuretic use in surgery; and intraoperative urine output monitoring. Catheter use may also be indicated for managing acute urinary retention, urinary obstruction, or to support healing of open pressure ulcers or skin grafts in select patients with incontinence. In exceptional cases, such as end-of-life care, patient requests for comfort may also justify catheterization. Alternatives, including intermittent catheterization or external condom catheters for men, should be used when feasible. Additionally, institutional policies should minimize catheter use perioperatively by encouraging early removal post-procedure and using bladder scanners to monitor volume and potentially avoid catheter reinsertion (Gould et al., 2010; Lo et al., 2014). When catheterization is necessary, prompt removal is essential once it is no longer required. Patients with indwelling catheters should be monitored regularly, ideally during daily rounds, and the catheter should be removed as soon as it is no longer indicated. Extended catheter use can be attributed to healthcare personnel being unaware of the catheter's presence. A systematic review showed that using "stop orders" for catheter removal reduced the duration of catheter use by 1.06 days and decreased CAUTI rates by 53% with reminders or stop orders (Meddings et al., 2014).

### Selection of urinary catheter

When selecting urinary catheters, the smallest possible gauge should be chosen to reduce urethral trauma (Hooton et al., 2010; O'Grady et al., 2011). Latex and silicone catheters have similar infection risks, regardless of hydrogel coating. For residents with chronic catheters, silicone catheters are less frequently obstructed, a benefit attributed to their larger bore size rather than the material itself. Silver alloy-coated catheters do not reduce CAUTI rates (Johnson et al., 1990; Pickard et al., 2012; Riley et al., 1995). Nitrofurazone-coated catheters may slightly reduce CAUTI incidence; however, they are associated with increased discomfort and a higher frequency of removal. Thus, current evidence does not recommend the routine use of antimicrobial-coated catheters (Gould et al., 2010).

### Catheter insertion and maintenance

Recommended practices for catheter insertion and maintenance include several measures supported by consensus and research showing a reduced bacteriuria rate with closed drainage systems. Routine daily periurethral cleaning with saline, soap, or antiseptic solutions, as well as adding antiseptics to drainage bags, do not provide additional benefits (Gould et al., 2010; Huth et al., 1992).

#### Catheter Insertion:

- Hand hygiene
- Selection of catheter type
- Aseptic technique with sterile equipment
- Use of barrier precautions
- Antiseptic meatal cleansing

### Catheter Maintenance:

- Hand hygiene
- Securing the catheter
- Maintaining a closed drainage system
- Aseptic sampling techniques
- Replacing systems if asepsis is compromised
- Avoiding irrigation solely for infection prevention

### Infection Monitoring:

Surveillance of catheter use, and related complications is crucial for documenting CAUTI rates within a facility, assessing intervention effectiveness, and benchmarking against reference rates (Gould et al., 2010; Lo et al., 2014). Surveillance alone has been associated with reduced infection rates in German ICUs, although this effect was more significant for ventilator-associated pneumonia and primary bloodstream infections than for CAUTIs (Gastmeier et al., 2011). Standard definitions should be applied to surveillance data, which should include catheter indication, dates of insertion and removal, urine culture results, and bacteremia monitoring. Key indicators include the CAUTI rate, CAUTI-associated bacteremia rate, and the proportion of catheter use that meets accepted indications. Outcomes are reported per device days; however, a successful infection prevention program that minimizes catheter use may see a higher infection rate per device day due to fewer low-risk patients with catheters. Therefore, the standardized infection ratio based on total patient days should also be reported (Lo et al., 2014). Surveillance data should be reviewed by relevant personnel and committees and reported back to caregivers in patient care areas (Gould et al., 2010).

### Prevention of CAUTI in Long-Term Care Facilities:

For long-term care facilities, CAUTI prevention focuses primarily on residents with chronic indwelling catheters (Hooton et al., 2010; Nicolle, 2009, 2012). Regular, systematic reviews of residents with chronic catheters should determine the continued necessity of catheterization. Bacteriuria in these patients is generally unavoidable, so interventions should emphasize catheter removal whenever feasible, minimizing trauma, and early identification of obstruction. Chronic indwelling catheters should not be routinely changed; replacement should occur only if there is obstruction, malfunction, or when symptomatic urinary infections are treated with antimicrobials. For mobility, residents with chronic catheters may use a leg bag, and facility policies should address bag reuse, cleaning, and replacement (Smith et al., 2008). Antimicrobial therapy for bacteriuria in these patients does not reduce CAUTI incidence and may lead to increased antibiotic resistance; therefore, asymptomatic bacteriuria should not be treated (Nicolle, 2012).

### Guidelines:

Evidence-based guidelines are available to support the development of CAUTI prevention programs, with a focus on minimizing catheter use, establishing catheter

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insertion and maintenance policies, choosing appropriate catheters, monitoring CAUTI and catheter use, and establishing quality indicators (Gould et al., 2010; Hooton et al., 2010; Lo et al., 2014; Pratt et al., 2001, 2007).

### Program Implementation:

Effective infection prevention and control programs are essential for reducing CAUTI rates, and improved outcomes have been reported following program implementation (Fakih et al., 2012; Marigliano et al., 2012; Rosenthal et al., 2012; Titsworth et al., 2012). Programs should be customized to address the specific needs, population characteristics, and resources of each facility, with senior management leadership being a critical element (Saint et al., 2008).

Support for these programs includes policies for catheter use, selection, insertion, and maintenance; adequate staffing; staff education; and access to appropriate supplies. Documentation systems, including electronic records with reminders for catheter removal, should be established for tracking urinary catheter use, indications, and dates of insertion and removal. Bundled approaches to CAUTI prevention, which include education, guidelines for insertion and maintenance, and CAUTI surveillance, have demonstrated a 37% reduction in CAUTI rates in ICUs across 15 developing countries (Rosenthal et al., 2012). A statewide initiative in Michigan developed a CAUTI prevention bundle with practical recommendations structured around “engage and educate,” “execute,” and “evaluate” concepts (Saint, Olmsted, et al., 2009).

## 2. Conclusion

In conclusion, the prevention of catheter-associated urinary tract infections (CAUTIs) remains a critical focus in healthcare due to their prevalence and impact on patient outcomes. A multi-faceted approach is essential for effective prevention, combining the avoidance of unnecessary catheter use with careful selection of catheter type, adherence to aseptic insertion and maintenance practices, and ongoing monitoring and education of healthcare personnel. Regular review of indwelling catheter necessity, implementation of CAUTI care bundles, and the establishment of systematic surveillance programs with benchmarking can significantly reduce infection rates. Furthermore, the development of innovative catheter materials and biofilm-resistant coatings may offer promising solutions for the future. A strong commitment from healthcare institutions and senior management, alongside evidence-based guidelines, is imperative for sustaining these preventive measures and improving patient safety in diverse healthcare settings.

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