Urinary Catheter-Associated Infections

Elizabeth Scruggs-Wodkowski, MD[a,b,*], Ian Kidder, MD[a,b], Jennifer Meddings, MD, MSc[c,d,e,f], Payal K. Patel, MD, MPH[g]

KEYWORDS

• Infection prevention • Catheter-associated urinary tract infection
• Healthcare-associated infection • Urinary catheter

KEY POINTS

- Catheter-associated urinary tract infections are one of the most common hospital-acquired infections and incur significant cost to the health care system.
- Hospital-acquired pathogens are a source of multidrug resistance.
- Duration of the indwelling urinary catheter is a major risk factor for developing an associated urinary tract infection.
- Prevention efforts, including surveillance, intervention bundles, and collaborative efforts, have been effective in reducing catheter-associated urinary tract infections.

INTRODUCTION

Catheter-associated urinary tract infections (CAUTIs) are a common source of hospital-associated infections (HAIs). A study from 2003 found that approximately 70% to 80% of urinary tract infections (UTIs) diagnosed in the hospital are catheter associated.[1] Although CAUTIs have decreased in proportion to non-device associated UTIs according to a recent 2019 study, they still make up a significant percentage among

[a] Division of Infectious Diseases, Department of Internal Medicine, Veterans Affairs Ann Arbor Healthcare System, Ann Arbor, MI 48105, USA; [b] Division of Infectious Diseases, Department of Internal Medicine, University of Michigan Medical School, University Hospital South F4012A, 1500 East Medical Center Drive, Ann Arbor, MI 48109, USA; [c] Division of General Medicine, Department of Internal Medicine, University of Michigan Medical School, Ann Arbor, MI 48109, USA; [d] Division of General Pediatrics, Department of Pediatrics, University of Michigan Medical School, East Medical Campus, 4260 Plymouth Road, Room F224, Ann Arbor, MI 48109, USA; [e] Center for Clinical Management Research, Veterans Affairs Ann Arbor Healthcare System, Ann Arbor, MI 48109, USA; [f] Department of Medicine, Veterans Affairs Ann Arbor Healthcare System, Ann Arbor, MI 48105, USA; [g] Division of Infectious Diseases, Intermountain Medical Center, 5171 South Cottonwood Street, Suite 350, Murray, UT 84107, USA
* Corresponding author. VA Ann Arbor Healthcare System, 2215 Fuller Road, Ann Arbor, MI, 48105.
E-mail address: escruggs@med.umich.edu

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hospitalized patients.[2] Urinary catheters are one of the most frequently utilized medical devices in the hospital, and an integrative review from 2014 has found that up to half of patients with urinary catheters may not have had an appropriate indication prior to placement.[3]

Infectious complications from urinary catheters are common, with the National Healthcare Safety Network (NHSN) documenting CAUTI rates up to 0.754 per 1000 catheter days for adult hospitalized patients in 2020.[4] Additional prevalent adverse events include urethral inflammation, urethral strictures, mechanical trauma, and impaired mobility.[4] CAUTIs have been associated with increased hospital length of stay, and financial burden from CAUTIs ranges from approximately US$600 to US$1700 per patient.[5–7]

It is estimated that the majority of CAUTIs are preventable, and various strategies to decrease CAUTI rates have shown efficacy.[4,8] CAUTI rates are reported to the NHSN under the Centers for Medicare and Medicaid Services (CMS) as a requirement of participation. Furthermore, the CMS no longer reimburses hospitals for costs associated with CAUTI, making CAUTI prevention a priority for most hospitals.[9] This summary article reviews definitions, epidemiology, risk factors, and preventative strategies for CAUTI in adult patients, including new recommendations published in the 2022 compendium update by the Infectious Diseases Society of America (IDSA), the Society for Healthcare Epidemiology of America (SHEA), and the Association for Professionals in Infection Control and Epidemiology (APIC).[4]

DIAGNOSIS: WHAT IS A CATHETER-ASSOCIATED URINARY TRACT INFECTION?

CAUTI remains fundamentally a clinical diagnosis, as no single laboratory test can reliably indicate true infection. Bacteriuria and pyuria alone are unpredictable indicators, especially in the presence of indwelling catheter devices where bacterial colonization is common.[10,11] Surveillance definitions may inadvertently designate asymptomatic bacteriuria as CAUTI when fever is viewed as an independent marker, even if an alternative source of fever is identified.[12] Clinical definitions such as those developed by the IDSA may help minimize overdiagnosis in patients with asymptomatic bacteriuria but are less easy to apply to specific patients.[13] The NHSN's updated CAUTI definition from 2015 has been adopted across the United States and has excluded yeast as a pathogen as well as increased the urine culture bacterial threshold to greater than 10^5 colony-forming units per milliliter.[14,15] **Fig. 1** demonstrates one example of a surveillance algorithm for CAUTI, including components of both NHSN and IDSA CAUTI definitions.

PATHOGENESIS

The innate defense system for prevention of UTIs in humans includes the length of the urethra, spontaneous voiding to clear the urinary tract of ascending bacteria, the microbiome and the genitourinary and gastrointestinal tissues, as well as the innate and adaptive immune system in the human urinary system.[16–21] Indwelling catheters disrupt this system by providing a surface on which bacteria can form biofilms. This hearty bacterial matrix can better evade the human defense system and ascend the catheter into the bladder in as few as 1 to 3 days.[1,22] As bacteria grow more slowly within a biofilm, antimicrobials may also prove less effective in treatment.[1]

Most bacteria implicated in CAUTI are endogenous to the patient, originating from the gastrointestinal tract or perineum.[23] A smaller proportion are the result of cross-contamination that occurs at the time of catheter insertion or maintenance, due to poor hand hygiene or poor technique.[1,23] Nosocomial infection clusters have been observed in roughly 15% of episodes of health care-associated bacteriuria and

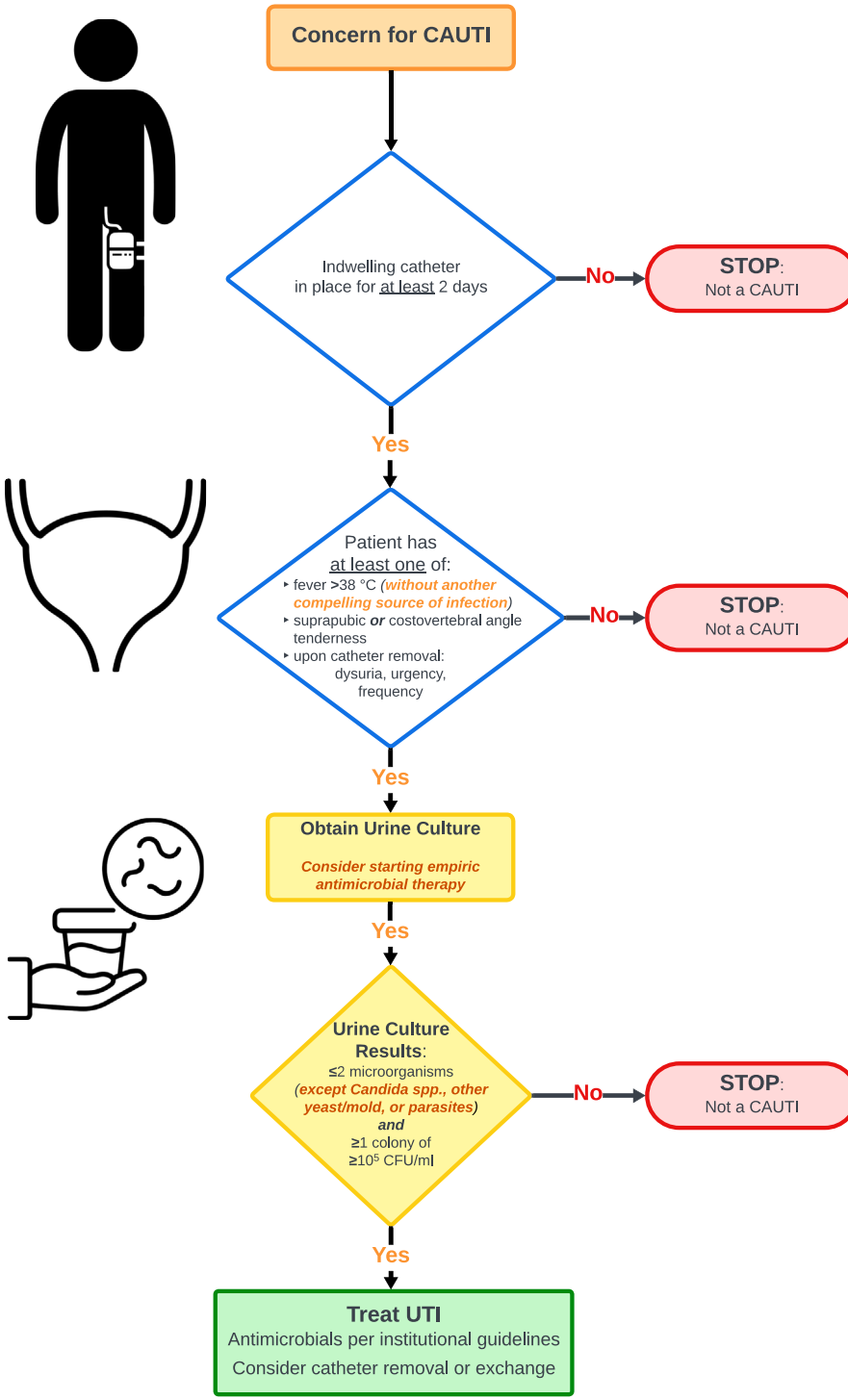

Fig. 1. CAUTI surveillance algorithm.

have been associated with transmission of multidrug-resistant organisms such as Klebsiella spp.[1,12,24] Hematogenous spread is a rare cause of UTI and often associated with Staphylococcus spp and hospital-acquired urinary tract-related bloodstream infections are rare but can be deadly and also often associated with presence of urinary catheter and Staphylococcus spp.[25]

EPIDEMIOLOGY OF CATHETER-ASSOCIATED URINARY TRACT INFECTION

Descriptive Epidemiology

Prevention efforts have resulted in a substantial decline in CAUTI rates over the last several decades.[26] CAUTI rates nationally, reported through the NHSN in 2013, ranged from 1.3 to 5.3 per 1000 catheter days in the intensive care unit (ICU) setting and 0.2 to 3.2 per 1000 catheter days on general care wards.[27] Between 2021 and 2022, a 12% reduction in CAUTI incidence was reported nationally, with the greatest decrease observed in the ICU.[28] HAI rates generally were impacted by the coronavirus 2019 pandemic, with reports of increases in CAUTI rates ranging from 36% to 43%.[26,29] A conflicting study found no significant change in CAUTI rates, although the retrospective analysis only evaluated the initial 6 months of the pandemic in comparison to the prior calendar year.[30]

Microbial Etiology

Organisms commonly identified in CAUTI are Enterobacteriaceae (ie, *Escherichia coli*, Klebisella spp, and Proteus spp, among others) but other pathogens are increasing in prevalence, including Pseudomonas and Enterococcus spp, particularly in the ICU setting.[31] A rise in antimicrobial resistance has also been observed, with NHSN summary data from 2015 to 2017 showing 31% of *E coli* isolates to be fluoroquinolone resistant. Extended-spectrum beta-lactamases (ESBLs) were found in roughly 16% of Klebsiella spp and *E coli* isolates in the ICU, and an even greater percentage of Klebsiella spp were found to have ESBL (48%) or carbapenem resistance (23.1%) mechanisms in long-term acute care settings.[31]

Risk Factors

The most important modifiable risk factor for developing infection is duration of catheterization, and reducing unnecessary placement and duration of catheters are at the forefront of CAUTI preventative strategies.[32–34] The longer duration of catheterization the greater likelihood of bacteriuria, such that it is estimated that all patients with indwelling catheters for longer than 1 month will develop bacteriuria.[12] Other modifiable risk factors of importance include proper hand hygiene, insertion technique, and maintaining a closed drainage system.[10,35]

In addition, host-level risk factors can place individual patients with indwelling catheters at a higher risk of infection. People with vaginas have shorter urethras and therefore have a greater likelihood of developing bacteriuria than people with penises. Age greater than 50 years has also been found to be an independent risk factor.[10,35] The development of health care-associated urinary-tract-related bloodstream infection is rare, occurring in less than 4% of CAUTIs.[36,37] Specific risk factors for UTI-associated bacteremia include male sex, neutropenia, and renal disease.[37–39] An overview of CAUTI risk factors, both modifiable and non-modifiable, can be seen in **Table 1**.

SURVEILLANCE

Surveillance of CAUTI rates annually provides important metrics that help monitor trends and provide critical feedback to infection prevention efforts at the national,

Table 1
Risk factors for catheter-associated urinary tract infection

Host-Level Risk Factors for UTI Even in Patients Without Indwelling Catheters[10,35,38]	Modifiable Risk Factors for CAUTI	Host-Level Risk Factors for Health Care-Associated Urinary Tract-Related Bloodstream Infection[36–39]
• Female sex or people with female genitourinary anatomy • Older age, ie, >50 years old • Diabetes • Immobility • Urinary retention • Structural urologic abnormalities	• Duration of catheter • Not maintaining a closed drainage system • Poor insertion technique • Poor hand hygiene	• Neutropenia • Renal disease • Male sex or people with male genitourinary anatomy

state, and local level.[28] The Centers for Disease Control and Prevention, which oversees the NHSN, tracks HAIs including CAUTI across 4 health care settings: acute care hospitals, critical access hospitals, inpatient rehabilitation centers, and long-term acute care hospitals. The NHSN definition of CAUTI has become the standard for surveillance and interhospital comparison.[22]

Diagnosing CAUTI remains challenging as bacteriuria is common in the setting of catheterization and therefore is not a reliable indicator of true infection.[11] Cultures may also be impacted by poor collection technique and therefore misleading.[40] Diagnosis must be made within the clinical context including urine culture data, clinical signs and symptoms, and catheter duration or recent removal.[41] Of note, the NHSN definition defines fever as an independent indicator of CAUTI, which may not correlate with a true urinary infection if an alternate source is present.[4]

Urine cultures are often collected as part of a fever evaluation regardless of specific urinary symptoms. This may lead to inappropriate treatment of asymptomatic bacteriuria when positive. Antimicrobial stewardship efforts have focused on appropriate indications for urine cultures in patients with and without an indwelling catheter to minimize treatment of asymptomatic bacteriuria.[42,43] Research has shown that incorporating appropriate indications for urine culture testing into the electronic medical record (EMR) helps decrease unnecessary testing and treatment.[44–46]

Traditionally, the most widely accepted CAUTI surveillance rate is the number of CAUTIs per 1000 catheter days, as monitored through the NHSN and endorsed by the IDSA, SHEA, and APIC.[4,47] However, as efforts to prevent initial placement of an indwelling urinary catheter increase, utilizing this metric may result in a contradictory increase in CAUTI rates.[48] Updated guidelines suggest consideration of patient days for the denominator at institutions where indwelling catheter use has declined or the risk profile has changed.[48] Currently, CAUTI measures available in the NHSN still rely on number of CAUTI per 1000 catheter days.[49]

PREVENTION

General Strategies for Prevention

Essential practices identified by the SHEA/IDSA/APIC 2022 compendium are often multidisciplinary and involve both the implementation of protocols and necessary infrastructure to prevent CAUTI.[4] The prevention of initial indwelling catheter placement is the first part of a protocol to manage adverse effects, as can be seen in

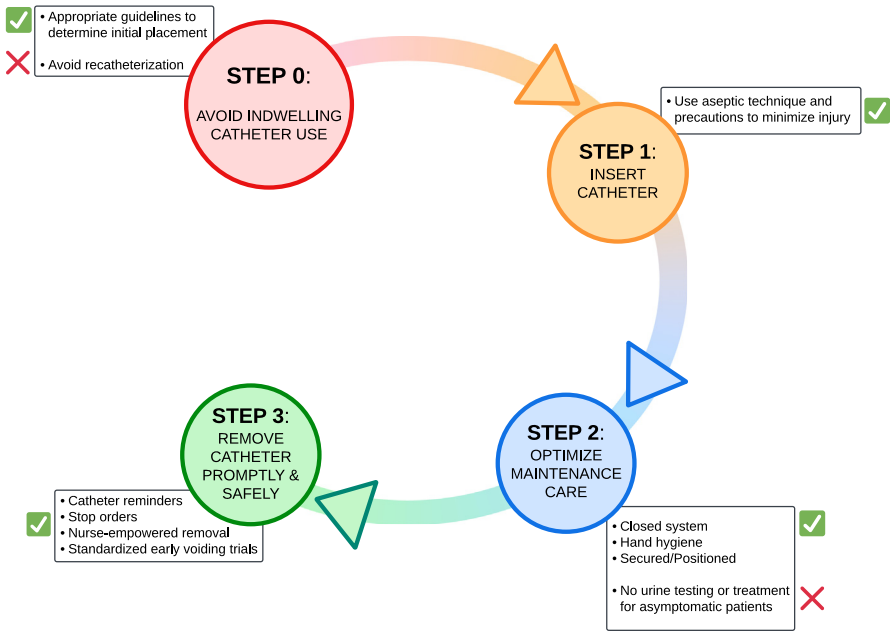

Fig. 2. Disrupting the Life Cycle of the Indwelling Urinary Catheter.

"Step Zero" of the Disrupting the Lifecycle of the Indwelling Urinary Catheter outlined by the compendium (Fig. 2).[4]

Once an indwelling urinary catheter has been placed, subsequent protocols at every step of the catheter life cycle can help lower infection and injury risk.[4] General strategies recommended include performing regular risk assessments on those patients with existing indwelling catheters and daily review of necessity.[10,35,50,51] This can be achieved on interdisciplinary care rounds or through the utilization of EMR reminders with stop/renewal orders prompting practitioners to reassess catheter necessity.[35,52] Infrastructure is also seen as a key part of CAUTI prevention and includes the provision of bladder scanners, incontinence supplies, and alternatives to indwelling catheters to mitigate catheter placement as a primary management tool of urinary issues.[53] These strategies and others are summarized in Box 1.

Appropriate Indwelling Catheter Use

Acceptable indications for indwelling urinary catheter use should be standardized within an institution to prevent unnecessary placement. Criteria for use can be embedded in daily risk assessment protocols or placed within the EMR to assist providers in clinical decision making. While expert consensus has identified criteria for indwelling urinary catheter use, robust research to assess appropriateness is lacking.[35,54] Examples of appropriate indications for use include hourly assessment of clinically indicated urine output in ICU patients (eg, for assessment of volume resuscitation, diuretic use, or vasopressors), management of acute urinary retention, or assistance in healing open pressure ulcers that risk contamination from urinary incontinence.[52] Selected surgical procedures, including urologic surgery, or surgery involving contiguous structures of the genitourinary tract, prolonged surgery, or the need for volume management intraoperatively are also appropriate indications for urinary catheter placement.[54] Finally,

Box 1
Strategies to prevent catheter-associated urinary tract infection

Strategies for prevention of CAUTI

Infrastructure and resources

- Perform regular risk assessments to identify and remove catheters when no longer necessary
- Ensure bladder management supplies are readily available, for example, bladder scans, incontinence management supplies, and external catheters
- Implement protocols to address multiple steps of the catheter life cycle (see Fig. 2) and consider embedding within the EMR
- Perform surveillance for CAUTI and standardize urine culture ordering

Education and training

- Educate health care providers on insertion, care, and maintenance of indwelling catheters
- Provide regular trainings and competency assessments for catheter care
- Educate providers on alternatives for bladder management, including intermittent catheterization and external catheters
- Train clinicians on appropriate indications for urine culturing and collection of samples

Insertion and maintenance

- Insert catheters only when necessary and leave in place only as long as indications remain
- Use appropriate aseptic technique for catheter insertion with hand hygiene
- Use a catheter with the smallest diameter feasible to minimize trauma
- Properly position and secure indwelling catheters
- Maintain a closed drainage system and unobstructed urine flow

some exceptions can be made for palliative or end-of-life care if appropriate to address a patient's specific goals to reduce pain or discomfort.

Alternatives to Indwelling Urinary Catheters

Whenever possible, alternatives to an indwelling catheter should be considered to reduce the risk of UTIs. Common alternatives include intermittent catheterization and external catheters. Indications for their use have previously been described in the Ann Arbor Criteria for appropriate urinary catheter use.[52] Intermittent straight catheterization should be considered in patients with urinary retention that can be adequately managed with a maximum catheterization frequency of every 4 hours, appropriate management of urinary incontinence (including in setting pressure ulcers that cannot be kept clear of urine by other means), daily or post-void urine volume measurements, management of urine in patient with strict temporary immobility, and for random urine sample (sterile or nonsterile) collection. Earlier studies showed that intermittent catheterization reduces the risk of UTI compared to indwelling catheters in patients with neurogenic bladder, although a more recent Cochrane review cautions there is inconclusive evidence to extrapolate this to the general patient population.[55,56] Given documented evidence of urinary retention and bladder distention in postoperative patients undergoing intermittent catheterization, portable bladder ultrasound should be considered to attenuate this risk.[57,58]

Other alternatives to indwelling catheters are external catheters, with multiple devices available for male and female patients.[59] These commonly include the condom catheter for men (and more recently the glans-adherence devices for men) and the wicking devices for women with 2 common brands including Purewick© and Primafit©.[60,61] Indications for external urinary catheters include management of incontinence (including in the setting of some open pressure ulcers and moderate-to-severe incontinence-associated dermatitis when non-catheter strategies to manage the incontinence or protect the skin have been inadequate), daily urine volume

measurement, and as part of comfort-focused care in the dying patient.[52] Male external catheters are appropriate for obtaining 24 hour and also random urine samples (including for chemical and cell sample tests, and sterile samples for culture if obtained after applying a new external catheter using sterile technique). Because of the wicking materials in the current female urinary devices, female external catheters are appropriate for measuring 24 hour samples, and recent studies also support collecting random non-sterile urine samples although the wicking material likely influences accuracy of cell counts, cast evaluation, cytology, etc.[62,63] These external devices may reduce the risk of CAUTI in both male and female patients, as CAUTI (which is currently defined in relation only to indwelling urinary catheters) does not occur in patients without current or recent indwelling catheters, and currently, there is no standard definition for reporting external catheter-associated UTIs.[64] Nonetheless, external catheters should only be utilized when appropriately indicated, as there are concerns for possible associate non-catheter-associated UTIs and skin injury.[64] **Fig. 3** outlines the various types of catheters, both internal and external, commonly used.[65]

Proper Techniques for the Insertion and Maintenance of Urinary Catheters

If an indwelling urinary catheter is deemed necessary for patient care, and no suitable alternative is available, insertion and maintenance of the catheter can be optimized for infection prevention. Indwelling urinary catheters should remain in place only as long as necessary. Insertion of the catheter should be performed using aseptic technique and appropriate hand hygiene. Contamination of the sterile catheter during insertion is unfortunately common and was observed to occur in more than half of insertions in one observational study within the emergency department.[66] Consider having 2 health care providers work together (eg, "buddy system") when inserting indwelling

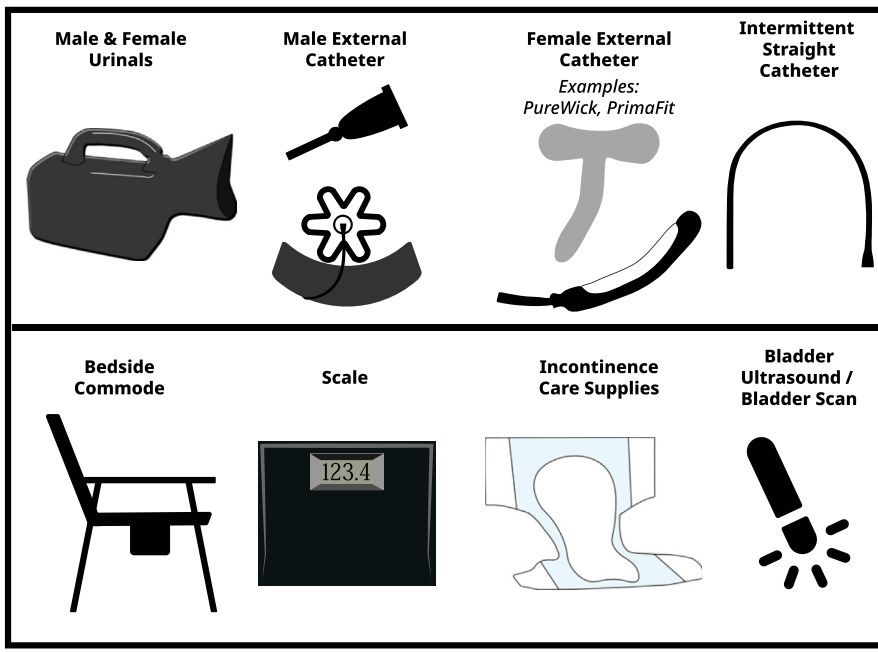

Fig. 3. Alternatives to indwelling urinary catheters.

catheters, to help observe for and reduce contamination of the sterile catheter during insertion. When possible, the smallest diameter catheter should be used to minimize trauma to the urethra, and the catheter should be properly secured and positioned. Maintaining unobstructed urine flow includes keeping the collecting bag below the level of the bladder, ensuring no kinks or obstruction of the tubing, emptying the collecting bag regularly, and keeping the collecting bag off the floor.[67,68] While in place, sterility of the catheter and collecting system can be further secured by using a closed drainage system, with system replacement when breaks in aseptic technique, disconnection, or leakage occur.[68,69] Routine hygiene of the genitourinary area is important although cleaning the meatal area with antiseptic solutions remains an unresolved issue in the 2022 compendium.[4,70] Alcohol-based cleaning products should be avoided for use on a patient's skin.[68,69]

Approaches that Should Not Be Considered a Routine Part of Catheter-Associated Urinary Tract Infection Prevention

The updated SHEA/IDSA/APIC 2022 compendium makes several recommendations regarding approaches that should not be used as part of usual CAUTI prevention practices. These include the use of antimicrobial or antiseptic-impregnated catheters, breaking a closed collecting system, and catheter irrigation.[4] Routine screening for asymptomatic bacteriuria is likewise not endorsed with the exception of pregnant persons or patients undergoing endoscopic urologic procedures.[71] Treatment of asymptomatic bacteriuria and the routine use of systemic antimicrobials as prophylaxis are discouraged, as the risk of adverse antimicrobial effects outweighs the potential benefit for CAUTI prevention. Furthermore, patient conditions, both anatomic and immunologic, predispose the patient to recurrence of bacteriuria following antimicrobial treatment.[4] Finally, the routine changing of catheters is not beneficial, although replacement can be considered at the timing of specimen collection if the urinary catheter is in place for longer than 7 days.[72,73]

Long-Term Care Settings

According to the National Center for Health Statistics, 1.3 million people resided in nursing homes in 2020.[74] Studies have shown that approximately 4% to 10% of these residents will have an indwelling Foley catheter during their stay.[75–77] UTI is the most commonly diagnosed infection in nursing homes, with up to 50% of residents with an indwelling catheter developing CAUTI.[78] Demonstrated risk factors for developing a UTI in the long-term care setting include dehydration, diuretic use, benign prostatic hyperplasia (BPH), and urinary/bowel incontinence.[79]

As in the acute care setting, Disrupting the Lifecycle of the Urinary Catheter (see **Fig. 2**) is an important strategy for reducing CAUTIs, including avoidance of indwelling catheters when not indicated, using aseptic technique with placement, maintaining proper care of catheters, and prompt removal of catheters when no longer necessary. Education of health care staff to maintain these practices is essential, as a wide discrepancy has been shown between research-proven recommendations and staff knowledge regarding urinary catheter care.[80] However, staff turnover in the long-term care setting is a major barrier to infection prevention.[81] A recent national project to reduce CAUTIs in nursing home residents demonstrated bundling these evidence-based practices with health care worker education and leadership engagement reduced CAUTI rates from 6.78 to 2.63 infections per 1000 catheter days (about a 50% decrease).[82] Additionally, there are well-established interventions that can reduce UTIs in the elderly, including maintenance of adequate hydration, preventing constipation, and promoting perineal hygiene.[83,84]

Implementation, Bladder Bundles, and Collaboratives

Implementation strategies to reduce CAUTI rates should employ both technical and socio-adaptive components to achieve success and maintain sustainability.[85] Technical strategies, such as the availability of hand sanitizers, sufficient bladder scanners, and automatic stop orders, are not sufficient alone to reduce CAUTI rates overtime and require socio-adaptive interventions that target modifications to organizational cultures or norms clinical practice.[86]

Multipronged approaches have been shown to be effective and reduce overall urinary catheter harm (Fig. 4). In one comparison study from 2013, hospitals that engaged in collaborative efforts, utilized bladder scanners, deployed EMR-based stop orders and reminders, or supported nursing-initiated urinary catheter removal saw a 25% decrease in CAUTI rates in comparison to other hospitals who did not use these practices.[87] The AHRQ Safety Program for Long-Term Care, engaging in technical and socio-adaptive interventions in combination, reduced CAUTI rates by 54% and culture orders by 15% in the nursing home setting.[82]

Sustainability remains a key aspect to any infection prevention approach and must be evaluated periodically after an intervention has been implemented. The 4 E's model to assess quality improvement projects, initially developed to reduce central line-associated bloodstream infections, can be effective when initiating CAUTI reduction programs.[88] The 4 E's involves, in part, engagement with a multidisciplinary team, peer networking, and the patient/family members; education through provision of materials, simulation trainings, and decision-making algorithms; execution of standardized care through daily assessments, EMR reminders, stop orders, and individual case reviews; and evaluation via performance measures and real-time audit and feedback.

Patient and Family Education

Clinicians should educate patients and families about the risks of CAUTI but also provide reassurance around physical signs that are commonly misperceived as indicative

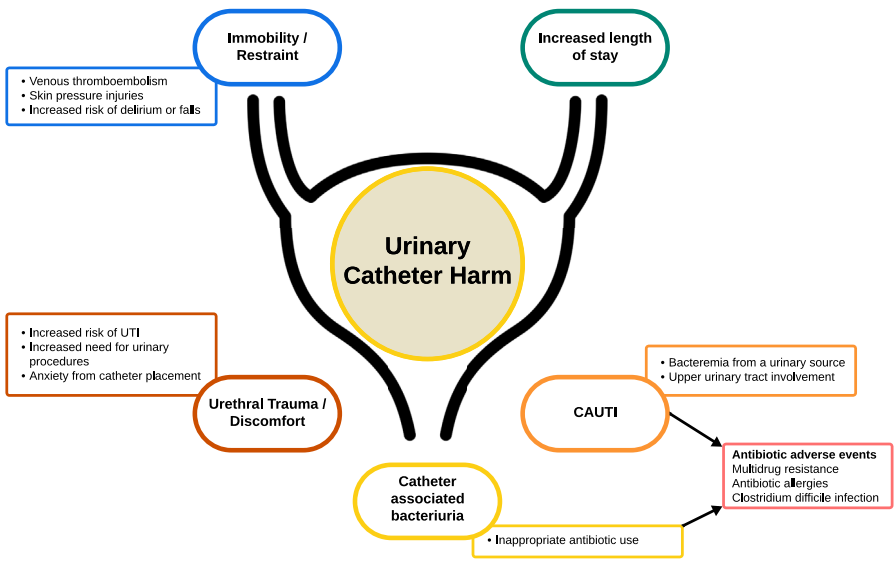

Fig. 4. Urinary catheter harm.

Box 2
Key points to share with patients and families about catheter-associated urinary tract infection

- Catheters should only be kept in place for as long they are absolutely needed to reduce the risk of infection.
- Cloudy, discolored, and malodorous urine without other localizing symptoms are not signs of infection.
- Any new symptoms of lower abdominal pain or back pain (one sided) or bloody urine might indicate an infection and warrant further testing.

of a urinary infection. Appropriate indications for obtaining a urine culture include new flank pain, acute hematuria, or pelvic discomfort. Odorous, cloudy, and discolored urine in the absence of other symptoms, however, are not indicators of infection and do not require further testing[4] (see **Box 2** for helpful bullet points to educate family members about CAUTI).

SUMMARY

CAUTIs are one of the most common health care-associated infections, can cause significant harm, and are related to increased cost to the health care system. The major risk factor for developing CAUTI is catheter duration, and infection prevention measures to limit placement and encourage early removal of catheters have helped decrease CAUTI rates. Other collaborative and interdisciplinary interventions have shown effectiveness, but implementation of these measures is not consistent across health care facilities. Interventional bundles involving infrastructure, education, and training can help further decrease CAUTI rates when adopted at the institutional level.

CLINICS CARE POINTS

- Educate health care providers on alternatives to indwelling catheters and ensure supplies are readily available in clinic (see **Fig. 3**).
- Consider implementing standardized clinical-decision-support tools within EMR systems in clinic to address multiple steps of the urinary catheter life cycle (see **Fig. 2**).
- Updated surveillance guidelines have increased the bacterial threshold in a urine culture to greater than 10^5 colony-forming units per milliliter and have excluded yeast as a pathogen when diagnosing CAUTI.
- Do not order urine culture testing for odorous, cloudy, or discolored urine in the absence of other clinical symptoms.
- Do not obtain reflex urine cultures based on urinalysis results without other clinical symptoms of infection.

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Dr Meddings has reported receiving honoraria from hospitals and professional societies devoted to complication prevention for lectures and teaching related to prevention and value-based purchasing policies involving catheter-associated urinary tract infection and hospital-acquired pressure ulcers. Dr Meddings also serves as an Associated Editor for the Annals of Internal Medicine: Clinical Cases journal.

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REFERENCES

1. Saint S, Chenoweth CE. Biofilms and catheter-associated urinary tract infections. Infect Dis Clin North Am 2003;17(2):411–32.
2. Strassle PD, Sickbert-Bennett EE, Klompas M, et al. Incidence and risk factors of non-device-associated urinary tract infections in an acute-care hospital. Infect Control Hosp Epidemiol 2019;40(11):1242–7.
3. Meddings J, Rogers MAM, Krein SL, et al. Reducing unnecessary urinary catheter use and other strategies to prevent catheter-associated urinary tract infection: an integrative review. BMJ Qual Saf 2014;23(4):277–89.
4. Patel PK, Advani SD, Kofman AD, et al. Strategies to prevent catheter-associated urinary tract infections in acute-care hospitals: 2022 Update. Infect Control Hosp Epidemiol 2023;44(8):1209–31.
5. Chant C, Smith OM, Marshall JC, et al. Relationship of catheter-associated urinary tract infection to mortality and length of stay in critically ill patients: a systematic review and meta-analysis of observational studies. Crit Care Med 2011;39(5):1167–73.
6. Hollenbeak CS, Schilling AL. The attributable cost of catheter-associated urinary tract infections in the United States: A systematic review. Am J Infect Control 2018;46(7):751–7.
7. Zimlichman E, Henderson D, Tamir O, et al. Health care-associated infections: AMeta-analysis of costs and financial impact on the US health care system. JAMA Intern Med 2013;173(22):2039–46.
8. Shuman EK, Chenoweth CE. Urinary Catheter-Associated Infections. Infect Dis Clin North Am 2018;32(4):885–97.
9. Meddings JA, Reichert H, Rogers MAM, et al. Effect of nonpayment for hospital-acquired, catheter-associated urinary tract infection: a statewide analysis. Ann Intern Med 2012;157(5):305–12.
10. Hooton TM, Bradley SF, Cardenas DD, et al. Diagnosis, prevention, and treatment of catheter-associated urinary tract infection in adults: 2009 International Clinical

Practice Guidelines from the Infectious Diseases Society of America. Clin Infect Dis 2010;50(5):625–63.
11. Tambyah PA, Maki DG. The relationship between pyuria and infection in patients with indwelling urinary catheters: a prospective study of 761 patients. Arch Intern Med 2000;160(5). https://doi.org/10.1001/ARCHINTE.160.5.673.
12. Chenoweth CE, Saint S. Urinary Tract Infections. Infect Dis Clin North Am 2016; 30(4):869–85.
13. Advani S, Fakih M. Healthcare-associated urinary tract infections. In: Weber D, Talbot T, editors. Mayhall's hospital epidemiology and infection prevention. 5th edition. Philadelphia, PA: Wolters Kluwer; 2021. p. 169–82.
14. Bardossy AC, Jayaprakash R, Alangaden AC, et al. Impact and Limitations of the 2015 National Health and Safety Network Case Definition on Catheter-Associated Urinary Tract Infection Rates. Infect Control Hosp Epidemiol 2017;38(2):239–41.
15. Advani SD, Lee RA, Schmitz M, et al. Impact of Changes to the National Healthcare Safety Network (NHSN) Definition on Catheter-Associated Urinary Tract Infection (CAUTI) Rates in Intensive Care Units at an Academic Medical Center. Infect Control Hosp Epidemiol 2017;38(5):621–3.
16. Kim DS, Lee JW. Urinary Tract Infection and Microbiome. Diagnostics 2023; 13(11). https://doi.org/10.3390/DIAGNOSTICS13111921.
17. Neugent ML, Hulyalkar NV, Nguyen VH, et al. Advances in Understanding the Human Urinary Microbiome and Its Potential Role in Urinary Tract Infection. mBio 2020;11(2). https://doi.org/10.1128/MBIO.00218-20.
18. Kawalec A, Zwolińska D. Emerging Role of Microbiome in the Prevention of Urinary Tract Infections in Children. Int J Mol Sci 2022;23(2). https://doi.org/10.3390/IJMS23020870.
19. Lacerda Mariano L, Ingersoll MA. The immune response to infection in the bladder. Nat Rev Urol 2020;17(8):439–58.
20. Bowyer GS, Loudon KW, Suchanek O, et al. Tissue Immunity in the Bladder. Annu Rev Immunol 2022;40:499–523.
21. Behzadi P, Kim CH, Pawlak EA, et al. Editorial: The innate and adaptive immune system in human urinary system. Front Immunol 2023;14. https://doi.org/10.3389/FIMMU.2023.1294869.
22. Chenoweth CE. Urinary Tract Infections: 2021 Update. Infect Dis Clin North Am 2021;35(4):857–70.
23. Tambyah PA, Halvorson KT, Maki DG. A Prospective Study of Pathogenesis of Catheter-Associated Urinary Tract Infections. Mayo Clin Proc 1999;74(2):131–6.
24. Jarvis WR, Munn VP, Highsmith AK, et al. The epidemiology of nosocomial infections caused by Klebsiella pneumoniae. Infect Control 1985;6(2):68–74.
25. Patel PK, Greene MT, Rogers MAM, et al. The Epidemiology of Hospital-Acquired Urinary Tract-Related Bloodstream Infection in Veterans. Am J Infect Control 2018;46(7):747.
26. Magill SS, O'Leary E, Janelle SJ, et al. Changes in Prevalence of Health Care-Associated Infections in U.S. Hospitals. N Engl J Med 2018;379(18):1732–44.
27. Dudeck MA, Edwards JR, Allen-Bridson K, et al. National Healthcare Safety Network report, data summary for 2013, Device-associated Module. Am J Infect Control 2015;43(3):206–21.
28. HAI progress report | HAI | CDC. 2022. Available at: https://www.cdc.gov/hai/data/portal/progress-report.html#2018. [Accessed 31 March 2024].
29. Baker MA, Sands KE, Huang SS, et al. The Impact of Coronavirus Disease 2019 (COVID-19) on Healthcare-Associated Infections. Clin Infect Dis 2022;74(10): 1748–54.

30. Fakih MG, Bufalino A, Sturm L, et al. Coronavirus disease 2019 (COVID-19) pandemic, central-line-Associated bloodstream infection (CLABSI), and catheter-Associated urinary tract infection (CAUTI): The urgent need to refocus on hardwiring prevention efforts. Infect Control Hosp Epidemiol 2022;43(1): 26–31.
31. Weiner-Lastinger LM, Abner S, Edwards JR, et al. Antimicrobial-resistant pathogens associated with adult healthcare-associated infections: Summary of data reported to the National Healthcare Safety Network, 2015-2017. Infect Control Hosp Epidemiol 2020;41(1):1–18.
32. Huth TS, Burke JP, Larsen RA, et al. Randomized trial of meatal care with silver sulfadiazine cream for the prevention of catheter-associated bacteriuria. J Infect Dis 1992;165(1):14–8.
33. Riley DK, Classen DC, Stevens LE, et al. A large randomized clinical trial of a silver-impregnated urinary catheter: lack of efficacy and staphylococcal superinfection. Am J Med 1995;98(4):349–56.
34. Johnson JR, Roberts PL, Olsen RJ, et al. Prevention of catheter-associated urinary tract infection with a silver oxide-coated urinary catheter: clinical and microbiologic correlates. J Infect Dis 1990;162(5):1145–50.
35. Gould CV, Umscheid CA, Agarwal RK, et al. Guideline for prevention of catheter-associated urinary tract infections 2009. Infect Control Hosp Epidemiol 2010; 31(4):319–26.
36. Chang R, Greene MT, Chenoweth CE, et al. Epidemiology of hospital-acquired urinary tract-related bloodstream infection at a university hospital. Infect Control Hosp Epidemiol 2011;32(11):1127–9.
37. Greene MT, Chang R, Kuhn L, et al. Predictors of hospital-acquired urinary tract-related bloodstream infection. Infect Control Hosp Epidemiol 2012;33(10): 1001–7.
38. Letica-Kriegel AS, Salmasian H, Vawdrey DK, 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). https://doi.org/10.1136/BMJOPEN-2018-022137.
39. Conway LJ, Carter EJ, Larson EL. Risk Factors for Nosocomial Bacteremia Secondary to Urinary Catheter-Associated Bacteriuria: A Systematic Review. Urol Nurs 2015;35(4):191.
40. Larocco MT, Franek J, Leibach EK, et al. Effectiveness of Preanalytic Practices on Contamination and Diagnostic Accuracy of Urine Cultures: a Laboratory Medicine Best Practices Systematic Review and Meta-analysis. Clin Microbiol Rev 2016;29(1):105–47.
41. 2024 NHSN urinary tract infection (UTI) checklist | NHSN. CDC; 2024. Available at: https://www.cdc.gov/nhsn/pdfs/checklists/Urinary-Tract-Infection-UTI-Checklist.pdf. [Accessed 31 March 2024].
42. Trautner BW, Grigoryan L, Petersen NJ, et al. Effectiveness of an Antimicrobial Stewardship Approach for Urinary Catheter-Associated Asymptomatic Bacteriuria. JAMA Intern Med 2015;175(7):1120–7.
43. Grigoryan L, Naik AD, Lichtenberger P, et al. Analysis of an Antibiotic Stewardship Program for Asymptomatic Bacteriuria in the Veterans Affairs Health Care System. JAMA Netw Open 2022;5(7):E2222530.
44. Munigala S, Jackups RR, Poirier RF, et al. Impact of order set design on urine culturing practices at an academic medical centre emergency department. BMJ Qual Saf 2018;27(8):587–92.
45. Baillie CA, Epps M, Hanish A, et al. Usability and impact of a computerized clinical decision support intervention designed to reduce urinary catheter utilization

and catheter-associated urinary tract infections. Infect Control Hosp Epidemiol 2014;35(9):1147–55.

46. Mullin KM, Kovacs CS, Fatica C, et al. A Multifaceted Approach to Reduction of Catheter-Associated Urinary Tract Infections in the Intensive Care Unit With an Emphasis on "Stewardship of Culturing.". Infect Control Hosp Epidemiol 2017; 38(2):186–8.
47. Chenoweth CE, Gould CV, Saint S. Diagnosis, Management, and Prevention of Catheter-Associated Urinary Tract Infections. Infect Dis Clin North Am 2014; 28(1):105.
48. Wright MO, Kharasch M, Beaumont JL, et al. Reporting catheter-associated urinary tract infections: denominator matters. Infect Control Hosp Epidemiol 2011; 32(7):635–40.
49. National Healthcare Safety Network. Urinary Tract Infection (Catheter-Associated Urinary Tract Infection [CAUTI] and Non-Catheter-Associated Urinary Tract Infection [UTI]) Events. cdc.gov. 2024. Available at: https://www.cdc.gov/nhsn/pdfs/pscmanual/7psccauticurrent.pdf. [Accessed 1 April 2024].
50. Panknin HT, Althaus P. Guidelines for preventing infections associated with the insertion and maintenance of short-term indwelling urethral catheters in acute care. J Hosp Infect 2001;49(2):146–7.
51. Pratt RJ, Pellowe CM, Wilson JA, et al. epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. J Hosp Infect 2007;65(SUPPL. 1). https://doi.org/10.1016/S0195-6701(07)60002-4.
52. Meddings J, Saint S, Fowler KE, et al. The Ann Arbor Criteria for Appropriate Urinary Catheter Use in Hospitalized Medical Patients: Results Obtained by Using the RAND/UCLA Appropriateness Method. Ann Intern Med 2015;162(9 Suppl): S1–34.
53. Meddings J, Greene MT, Ratz D, et al. Multistate programme to reduce catheter-associated infections in intensive care units with elevated infection rates. BMJ Qual Saf 2020;29(5):418–29.
54. Meddings J, Skolarus TA, Fowler KE, et al. Michigan Appropriate Perioperative (MAP) criteria for urinary catheter use in common general and orthopaedic surgeries: results obtained using the RAND/UCLA Appropriateness Method. BMJ Qual Saf 2019;28(1):56–66.
55. Shekelle PG, Morton SC, Clark KA, et al. Systematic review of risk factors for urinary tract infection in adults with spinal cord dysfunction. J Spinal Cord Med 1999;22(4):258–72.
56. Kidd EA, Stewart F, Kassis NC, et al. Urethral (indwelling or intermittent) or suprapubic routes for short-term catheterisation in hospitalised adults. Cochrane Database Syst Rev 2015;2015(12). https://doi.org/10.1002/14651858.CD004203.PUB3.
57. Oishi CS, Williams VJ, Hanson PB, et al. Perioperative bladder management after primary total hip arthroplasty. J Arthroplasty 1995;10(6):732–6.
58. Stevens E. Bladder Ultrasound: Avoiding Unnecessary Catheterizations. Medsurg Nurs 2005;14(4):249–53.
59. Newman DK. Types and Materials – External Urine Collection Devices. 2020. Available at: https://www.urotoday.com/library-resources/bladder-health/120651-types-and-materials-external-urine-collection-devices.html. [Accessed 31 March 2024].

60. Sage PrimaFit External Urine Management for the Female Anatomy | Stryker. Available at: https://www.stryker.com/us/en/sage/products/sage-primafit.html. [Accessed 9 July 2024].
61. The BD PureWickTM System - Official Site. Available at: https://www.purewickathome.com/on/demandware.store/Sites-BD_PureWick-Site/default/Default-Start?trkid=m8_sem_google_21080281395_163329327481_purewick&gad_source=1&gclsrc=aw.ds. [Accessed 9 July 2024].
62. Cassone M, Ameling J, Mody L, et al. Impact of external female urinary catheter use on urine chemistry test results. Am J Infect Control 2024. https://doi.org/10.1016/J.AJIC.2024.03.010.
63. Rose G, Pyle-Eilola AL. The Effect of Urine Collection with a Novel External Catheter Device on Common Urine Chemistry and Urinalysis Results. J Appl Lab Med 2021;6(6):1618–22.
64. Pryor N, Wang J, Young J, et al. Clinical outcomes of female external urine wicking devices as alternatives to indwelling catheters: a systematic review and meta-analysis. Infect Control Hosp Epidemiol 2024. https://doi.org/10.1017/ICE.2024.73.
65. Meddings J, Ameling J. Alternatives to Indwelling Catheter Use. Surgical Urinary Catheter Care Enhancement Safety Study (SUCCESS). 2024. Available at: https://msqc.org/wp-content/uploads/2024/04/Alternatives-to-indwelling-catheter-use_final.pdf. [Accessed 9 July 2024].
66. Manojlovich M, Saint S, Meddings J, et al. Indwelling Urinary Catheter Insertion Practices in the Emergency Department: An Observational Study. Infect Control Hosp Epidemiol 2016;37(1):117–9.
67. Willson M, Wilde M, Webb ML, et al. Nursing interventions to reduce the risk of catheter-associated urinary tract infection: part 2: staff education, monitoring, and care techniques. J Wound Ostomy Continence Nurs 2009;36(2):137–54.
68. Catheter Care and Maintenance | Agency for Healthcare Research and Quality. Available at: https://www.ahrq.gov/hai/quality/tools/cauti-ltc/modules/implementation/education-bundles/indwelling-urinary-catheter-use/catheter-care/slides.html. [Accessed 31 March 2024].
69. Manojlovich M. Catheter Maintenance. Bladdersafe Website. 2013. Available at: https://www.bladdersafe.org/uploads/5/6/5/0/56503399/indwelling_urinary_catheter_maintenance_supplement_052213_1.pdf. [Accessed 31 March 2024].
70. Mitchell B, Curryer C, Holliday E, et al. Effectiveness of meatal cleaning in the prevention of catheter-associated urinary tract infections and bacteriuria: an updated systematic review and meta-analysis. BMJ Open 2021;11(6). https://doi.org/10.1136/BMJOPEN-2020-046817.
71. Henderson JT, Webber EM, Bean SI. Screening for Asymptomatic Bacteriuria in Adults: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. JAMA, J Am Med Assoc 2019;322(12):1195–205.
72. Frontera JA, Wang E, Phillips M, et al. Protocolized Urine Sampling is Associated with Reduced Catheter-associated Urinary Tract Infections: A Pre- and Postintervention Study. Clin Infect Dis 2021;73(9):E2690–6.
73. Strategize Initiatives. Urine Culture Stewardship | HAI | CDC. Available at: https://www.cdc.gov/hai/prevent/cauti/indwelling/strategize.html. [Accessed 31 March 2024].
74. Post-acute and long-term care user demographic and health-related characteristics: United States, 2020. National Center for Health Statistics; 2023. Available at: https://www.cdc.gov/nchs/npals/webtables/overview.htm#table4. [Accessed 31 March 2024].

75. Rogers MAM, Mody L, Kaufman SR, et al. Use of urinary collection devices in skilled nursing facilities in five states. J Am Geriatr Soc 2008;56(5):854–61.
76. Tsan L, Langberg R, Davis C, et al. Nursing home-associated infections in Department of Veterans Affairs community living centers. Am J Infect Control 2010;38(6):461–6.
77. Castle N, Engberg JB, Wagner LM, et al. Resident and Facility Factors Associated With the Incidence of Urinary Tract Infections Identified in the Nursing Home Minimum Data Set. J Appl Gerontol 2017;36(2):173–94.
78. Montoya A, Mody L. Common infections in nursing homes: a review of current issues and challenges. Aging Health 2011;7(6):889–99.
79. da Silva JLA, da Fonseca CD, Stumm EMF, et al. Factors associated with urinary tract infection in a Nursing Home. Rev Bras Enferm 2021;74(Suppl 2). https://doi.org/10.1590/0034-7167-2020-0813.
80. Mody L, Saint S, Galecki A, et al. Knowledge of evidence-based urinary catheter care practice recommendations among healthcare workers in nursing homes. J Am Geriatr Soc 2010;58(8):1532–7.
81. Loomer L, Grabowski DC, Yu H, et al. Association between nursing home staff turnover and infection control citations. Health Serv Res 2022;57(2):322–32.
82. Mody L, Greene MT, Meddings J, et al. A National Implementation Project to Prevent Catheter-Associated Urinary Tract Infection in Nursing Home Residents. JAMA Intern Med 2017;177(8):1154–62.
83. Lean K, Nawaz RF, Jawad S, et al. Reducing urinary tract infections in care homes by improving hydration. BMJ Open Qual 2019;8(3). https://doi.org/10.1136/BMJOQ-2018-000563.
84. Charach G, Greenstein A, Rabinovich P, et al. Alleviating constipation in the elderly improves lower urinary tract symptoms. Gerontology 2001;47(2):72–6.
85. Meddings J, Chopra V, Saint S. Preventing hospital infections: real-world problems, realistic solutions. 2nd Edition. Oxford University Press; 2021. https://doi.org/10.1093/med/9780197509159.001.0001.
86. Greene MT, Gilmartin HM, Saint S. Psychological safety and infection prevention practices: Results from a national survey. Am J Infect Control 2020;48(1):2–6.
87. Saint S, Greene MT, Kowalski CP, et al. Preventing catheter-associated urinary tract infection in the United States: a national comparative study. JAMA Intern Med 2013;173(10):874–9.
88. Pronovost P, Berenholtz S, Needham D. Translating evidence into practice: a model for large scale knowledge translation. BMJ 2008;337(7676):963–5.