Urinary Tract Infections in Surgical Patients

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KEYWORDS

• Urinary tract infections • Catheter-associated urinary tract infection • CAUTI
• Urosepsis • Patient safety • Hospital acquired conditions

KEY POINTS

- Short-term catheter-associated urinary tract infections (CAUTI) are associated with increased patient hospital stay, morbidity, and mortality.
- CAUTI negatively impact public reporting of hospital safety and reimbursement.
- CAUTI are increased by unnecessary use of catheters and duration of catheterization.
- Understanding and educating care providers about appropriate indications for catheters and alternatives to indwelling urinary catheters can decrease the incidence of CAUTI.
- Developing institutional guidelines for appropriate use, duration, removal, and alternatives decreases the incidence of CAUTI.

INTRODUCTION

Scope of the problem

- Urinary tract infections (UTI) account for up to 40% of all health care–acquired infections.
- Nearly 80% of all UTI occur in patients with short-term urinary catheters and are tracked as catheter-associated UTI (CAUTI) by regulatory agencies.
- CAUTI increases patient morbidity and mortality, and increases health care costs.
- Hospital incidence of CAUTI is tracked by regulatory agencies and CMS, and affects public reporting on patient safety and hospital reimbursement.

The 2001 Institute of Medicine report, *To Err is Human*, highlighted the opportunity that exists for health care providers to decrease preventable nosocomial events and allow

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patient outcomes to fully reflect the positive care delivered.[1] This and subsequent reports focused public and regulatory attention on health care practices that are potentially preventable. The federal Agency for Healthcare Research and Quality and the Centers for Medicare and Medicaid Services (CMS) have identified a core set of potentially preventable patient safety events that are increasingly being used as publically reported indicators of hospital safety and quality.[2–4] In 2007, the CMS instituted a change in reimbursement policy whereby hospitals would be held financially responsible, with no increase in reimbursement, for the development of any of 8 preventable, hospitalization-related complications.[4] A subsequent rule change by CMS financially penalizes hospitals for the development of such predefined hospital-related complications.

Catheter-associated urinary tract infection (CAUTI) is a hospital-acquired condition that is recognized by Agency for Healthcare Research and Quality and CMS as a preventable patient safety event. Urinary catheters are widely used with 12% to 16% of all surgical and medical inpatients being exposed during a hospitalization.[5–7] Inpatient urinary tract infections (UTI) account for up to 40% of all health care–acquired infections in the United States.[8,9] Up to 80% of these UTI are urinary catheter associated.[6,10] Specifically, among surgical patients, rates of UTI range from 1.8% to 4.1% based on surgery type, and development of UTI has been associated with increased duration of hospital stay, increased incidence of surgical site infections, increased incidence of prosthetic infections, and increased mortality.[11–15] Financially, nosocomial UTI account for more than $400 million in increased annual health care costs.[16] The development of urinary complications are directly related to urinary catheter use and duration, and thus efforts to more accurately identify, manage, and prevent CAUTI are relevant in the quest to improve patient care and safety.

In addition to those with short-term urinary catheter needs, up to 5% of long-term care facility patients have indwelling urinary catheters, and long-term urinary drainage is a prescient concern for patients with spinal cord injury and other congenital and acquired urologic conditions.[10] Given the magnitude and preventable potential of CAUTI in patients with short-term urinary catheter needs, this review focuses primarily on the pathogenesis, evaluation, definition, management, and prevention of CAUTI in the patient with short-term urinary drainage needs.

PATHOGENESIS

Pathogenesis summary

- The presence and duration of catheterization are the strongest risk factors for bacteriuria development. Approximately 10% to 25% patients with bacteriuria progress to symptomatic UTI and 1% to 4% develop urosepsis.
- Microbial seeding of the urinary bladder occurs during catheter placement and subsequently owing to ascension of microbe-laden biofilms along urinary catheters.
- Biofilms form rapidly, within 1 to 3 days, on the intraluminal and extraluminal catheter surface. Biofilms are dynamic, with changes in the microbial populations and virulence over time.
- Biofilms on catheters encourage microbial growth and ascension into the urinary system, and hinder antimicrobial action.
- Extraluminal microbial colonization likely results from surrounding fecal contamination, whereas intraluminal colonization results from contamination of the closed collection apparatus.

The pathogenesis of UTI and urosepsis begins with bacteriuria—the acquisition of bacteria or fungi in the urinary bladder. In patients with indwelling urinary catheters or in patients with a recent history of indwelling urinary catheterization, the catheter serves as the most common route of access for microorganisms into the bladder. The presence and duration of indwelling urinary catheters is the strongest risk factor for developing bacteriuria, with a 3% to 10% risk of bacteriuria development per urinary catheter day.[17–20] Among patients with bacteriuria, approximately 10% to 25% develop UTI symptoms and 1% to 4% develop urosepsis.[12,17,21]

The initial infection after short-term catheter placement (<1 month) is commonly a monocolonization with *Escherichia coli*; however, in select circumstances, monocolonization with yeast species, *Enterococcus* species and *Pseudomonas aeruginosa* may also occur.[21] In patients with catheters for longer than 1 month, polymicrobial colonization with a variety of enterobacteriaceae and other gram-negative organisms, gram-positive organisms, and yeast is common with an average of 3 to 5 organisms isolated at any time point.[5] The most common yeast species is *Candida albicans*, with a growing incidence of *C glabrata* and *C tropicalis*. Moreover, in patients with longer term catheters, there is a greater incidence of resistant bacteria, particularly vancomycin-resistant enterococci and extended-spectrum β-lactamase–producing enterobacteriaceae.[6,22,23] The incidence of resistant microorganisms is presumably increasing owing to increased health care and antimicrobial exposure. Microbiologic studies have further revealed that the urinary catheter and bladder biofilm is a constantly evolving and dynamic environment with new organisms being continually incorporated in the biofilm, posing further challenges in the management of CAUTI.[21]

Urinary catheters facilitate bacteriuria either through direct inoculation of the bladder during catheter insertion or through biofilm ascension along the catheter. Direct inoculation can occur through breaks in aseptic technique and contamination with skin flora, or through tracking of bacteria along the urogenital tract. Biofilm formation and ascension along the urinary catheter into the urinary bladder is believed to be the primary mechanism for the development of bacteriuria.[6,17] Biofilms are a collection of microbial organisms that organize in a polysaccharide matrix on the extraluminal or intraluminal surface of the catheter.[6,17] Up to 66% of extraluminal biofilms originate from the bacteria on the surrounding tissues, with a majority of these bacteria being of gastrointestinal origin.[21] Formation of biofilms on the intraluminal surface of the catheter occurs mainly through contamination of the closed-system urine collection bag. The microbes identified on the intraluminal surface have been found to match microbes identified on the hands of health care personnel.[21]

Standard latex urinary catheters display a high propensity for biofilm formation owing to a favorable mix of hydrophobic and hydrophilic surface regions that allow for attachment and colonization by a wide variety of microorganisms. Additionally, the flagella and motility of common uropathogens, *E coli* and *P aeruginosa*, facilitate catheter surface attachment and secretion of the glycocalyces matrix needed for biofilm formation.[17,24,25] The ascension of the biofilm from the drainage apparatus to the bladder has been reported to take between 1 and 3 days, but may progress quicker in the setting of swarming urease-producing microorganism like *Proteus mirabilis* and *Providenci stuartii*.[26,27]

The presence of biofilms significantly impacts therapy, because the biofilm matrix reduces the effectiveness of antimicrobials. Microorganisms in biofilms display slower replication rates, thus blunting the effects of antimicrobials. This is particularly detrimental for bacteriostatic antimicrobials. Additionally, chemical signaling

within biofilms has been shown to affect gene regulation within bacteria, making them more resistant to antimicrobials.[28,29] Notably, factors affecting the conversion from colonization and bacteriuria to symptomatic bacteriuria and bacteremia remain unclear and do not seem to be associated with bacterial virulence.[17]

EVALUATION

Evaluation summary

- Fevers are often the only symptom of CAUTI.
- Urine culture, with or without urinalysis, is the standard for diagnosis of UTI.
- For catheters indwelling for fewer than 10 days, urine specimens can be collected from the sampling port or tubing puncture.
- For catheters indwelling for longer than 2 weeks, catheters should be replaced and specimens collected through the new catheter.

Evaluation of UTI in a hospitalized patient or a patient in intensive care can be challenging owing to concurrent medical conditions, chemical sedation, and the poor specificity of symptoms. In the unresponsive, chemically sedated, or altered patient, clinical evaluation is limited and a febrile reaction or unexplained leukocytosis should prompt collection of urine for analysis and culture. In the awake, responsive patient, the continued presence of an indwelling urinary catheter may mask the common symptoms of UTI, namely suprapubic tenderness, urinary frequency, dysuria, and stranguria.[5] As a result, other than fever, CAUTI are rarely associated with patient complaints in the awake, responsive patient. Patients with chronic indwelling catheters may experience advanced local symptoms of urethritis, periurethral abscesses, epididymitis or orchitis, and prostatitis.[30]

In patients with unexplained fever, leukocytosis, altered mental status, or clinical deterioration, urine culture with or without urinalysis remains the standard for diagnosis. Urine samples should ideally be obtained before antimicrobial initiation in patients with indwelling catheters and suspected symptomatic UTI. If the urinary catheter has been in place for fewer than 10 days, urine specimens can be collected through the sampling port or tubing puncture. In catheters indwelling for longer than 2 weeks, there is a risk for falsely elevated bacterial counts owing to biofilm contamination.[5,10,31] As a result, urinary catheters should be replaced upon suspicion of symptomatic UTI and a urine specimen collected through the newly inserted catheter.[5]

Accurate interpretation of results from urine culture and urinalysis affects the identification of CAUTI and subsequent therapy. Studies evaluating the correct detection of CAUTI based on US Centers for Disease Control and Prevention (CDC) definitions by general clinicians and infectious disease consultants found poor sensitivity and specificity, advocating for the need to further educate providers on definitions for CAUTI.[32]

DEFINITIONS

The National Healthcare Safety Network and CMS use the US Centers for Disease Control and Prevention definitions for identification and monitoring of CAUTI. Per the Centers for Disease Control and Prevention definitions, a CAUTI is an UTI

that develops in a patient who had an indwelling catheter in place at the time of, or within 48 hours before, infection onset. An indwelling catheter is specifically defined as a drainage tube inserted into the urinary bladder through the urethra, left in place, and connected to a closed collection system. As such, it excludes straight catheters, suprapubic catheters, nephrostomy tubes, and condom catheters (**Box 1**).[33]

Diagnosis of symptomatic UTI requires both the presence of symptoms and positive urine culture that is obtained either while the indwelling catheter is in place or within 48 hours of catheter removal. UTI are classified as symptomatic UTI or asymptomatic bacteremic UTI. The diagnosis of symptomatic UTI must include one of the following clinical signs that are not attributable to another source: Fever, suprapubic tenderness, or costovertebral angle tenderness. In patients with catheter removal in the preceding 48 hours, the presence of dysuria, urgency, and urinary frequency qualify as clinical signs of UTI. In addition to clinical signs, patients must have either a urine culture with greater than 10^5 colony-forming units, or a urine culture between 10^3 and 10^5 colony-forming units with a positive urinalysis. Positive urinalysis includes the presence of nitrates, leukoesterases, pyuria, or microorganisms on gram stain (see **Fig. 1**).[33]

Asymptomatic bacteremic UTI are diagnosed in patients without UTI symptoms. These patients must have a urine culture with greater than 10^5 colony-forming units and a positive blood culture with at least 1 matching uropathogen (gram negative bacilli, *Staphylococcus* spp., yeasts, β-hemolytic *Streptococcus* spp., *Enterococcus* spp., *Giardia vaginalis*, *Aerococcus urinae*, or *Corynebacterium* spp.) to the urine culture (see **Fig. 2**).[33] Patients with long-term catheters routinely have asymptomatic microbial colonization, and hence, a consensus conference defined symptomatic UTI as fever, new costovertebral angle tenderness, rigors, or new delirium without an alternative source.[30,34]

The complexities of the definition contribute to the challenge in correctly identifying and treating CAUTI. A strong grasp of the definitions for CAUTI is important, because accurate identification of CAUTI has ramifications on infection tracking, responsible antimicrobial use, performance improvement, and accurate public reporting and reimbursement.

MANAGEMENT

Management summary

- In the absence of clinical symptoms or signs, bacteriuria or funguria should not be treated with antimicrobial therapy.
- For symptomatic bacteriuria, empiric antimicrobial therapy is appropriate in the presence of high suspicion and high severity. Without high suspicion or severity, therapy can be deferred pending urine culture results.
- A 7-day course of antimicrobials is recommended for CAUTI, although shorter durations may be appropriate in select populations. Antimicrobials should be narrowed based on bacterial sensitivities.
- Catheters should be removed as soon as possible. If continued need exists, catheters in place for longer than 2 weeks should be replaced before initiating therapy.
- In patients with continuing epidural analgesia, catheter removal on the first postoperative day could be considered.

Box 1
Minimum criteria for CAUTI

Necessary requirements for CAUTI consideration

- Occurs in a hospital setting
- Not present or incubating at time of admission
- Indwelling catheter (does not include straight catheterizations, suprapubic catheters, nephrostomy catheters)
- CDC CAUTI diagnostic criteria (Figs. 1 and 2)

Abbreviations: CAUTI, catheter-associated urinary tract infection; CDC, US Centers for Disease Control and Prevention.

Asymptomatic Catheter-Associated Urinary Tract Infection

In patients with afebrile, asymptomatic bacteriuria or funguria, antimicrobial treatment does not alter the natural progression to symptomatic infection or improve outcomes.[5] A randomized trial investigating the effect of antimicrobial therapy and catheter

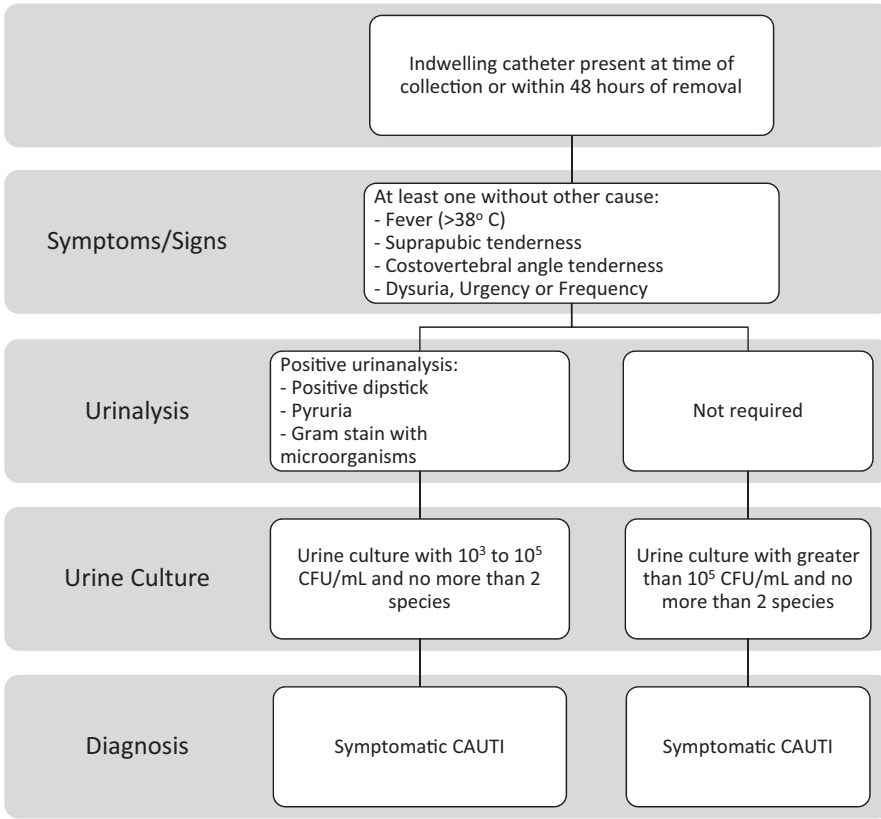

Fig. 1. US Centers for Disease Control and Prevention (CDC) criteria for diagnosis of symptomatic catheter-associated urinary tract infection (CAUTI). (*From* US Centers for Disease Control and Prevention. National Healthcare Safety Network (NHSN) Manual. Atlanta (GA): US Centers for Disease Control and Prevention; 2013.)

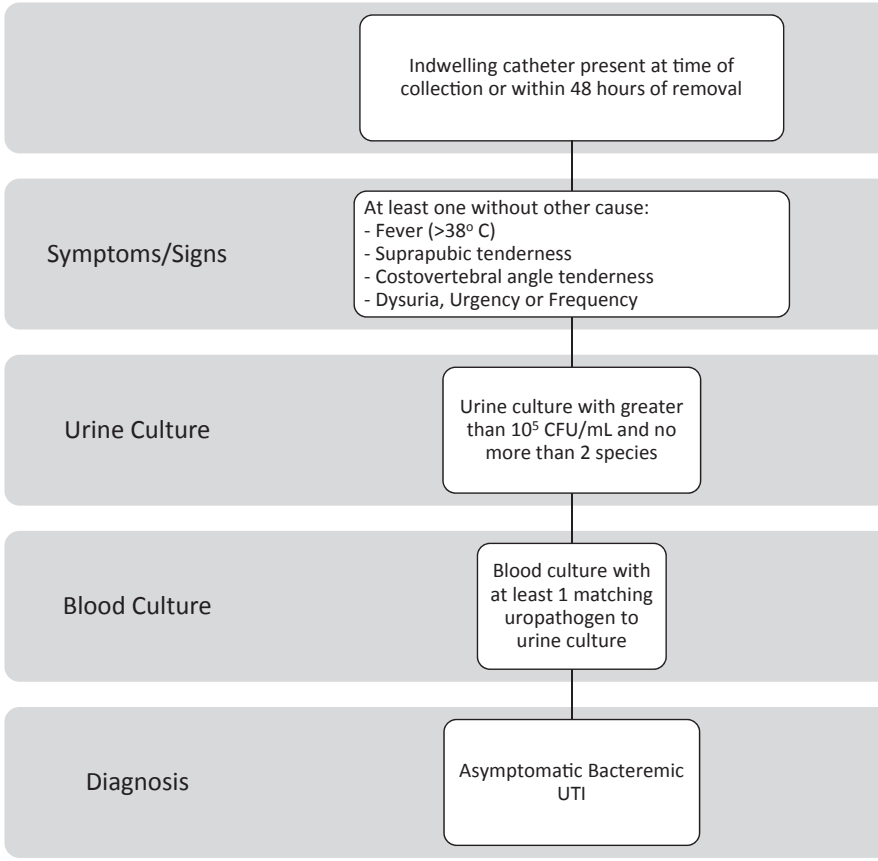

Fig. 2. US Centers for Disease Control and Prevention (CDC) criteria for the diagnosis of asymptomatic bacteremic urinary tract infection (UTI). (*From* US Centers for Disease Control and Prevention. National Healthcare Safety Network (NHSN) Manual. Atlanta (GA): US Centers for Disease Control and Prevention; 2013.)

change on the rates of urosepsis in patients in intensive care with asymptomatic bacteriuria after 48 hours of catheterization found no differences in rates of urosepsis and found no decrease in recurrence of asymptomatic bacteriuria at 7 and 15 days after catheterization.[35] Similarly, the use of azoles to treat asymptomatic funguria revealed initial high eradication rates, but equivalent recurrence of funguria at 2 weeks between treated and untreated patients.[36] Therefore, treatment for asymptomatic CAUTI is not recommended.

In patients with long-term catheters, antimicrobial therapy for asymptomatic bacteriuria similarly does not change the prevalence of bacteriuria or decrease progression to symptomatic UTI.[5] In those undergoing intermittent catheterization, treatment of asymptomatic bacteriuria may contribute to increased frequency of resistant organisms in subsequent symptomatic UTI episodes.[5]

Symptomatic Catheter-Associated Urinary Tract Infection

Specific antimicrobial choice for the treatment of CAUTI should be tailored to institutional susceptibility and resistance patterns. Important biochemical characteristics of

antibiotics for UTI ought to include high urinary secretion and urinary drug levels. In patients with high severity of associated symptoms (eg. fevers, constitutional symptoms, hemodynamic instability) and high suspicion of UTI, empiric broad-spectrum parenteral antimicrobial therapy is appropriate. Cultures should be obtained, ideally before antibiotic initiation, and antibiotics narrowed or changed to fit culture sensitivities. In patients with mild symptoms, or patients with other suspected etiologies, it is reasonable to delay antimicrobial therapy until after return of urine culture results to minimize inappropriate antimicrobial use and to minimize the risk of antimicrobial-related adverse effects (**Fig. 3**).

There are varying recommendations regarding the duration of antimicrobial therapy in CAUTI.[10,37] For patients with continued urinary catheter needs, the 2009 Infectious Disease Society of America recommendations suggest a 7-day course.[10] However, there is evidence to suggest that shorter courses of antimicrobial therapy may be equally effective. In a randomized trial of women with catheter-associated bacteriuria and lower urinary tract symptoms, single-dose therapy with trimethoprim–sulfamethoxazole was as effective as a 10-day course.[38] Similarly, a double-blind, randomized

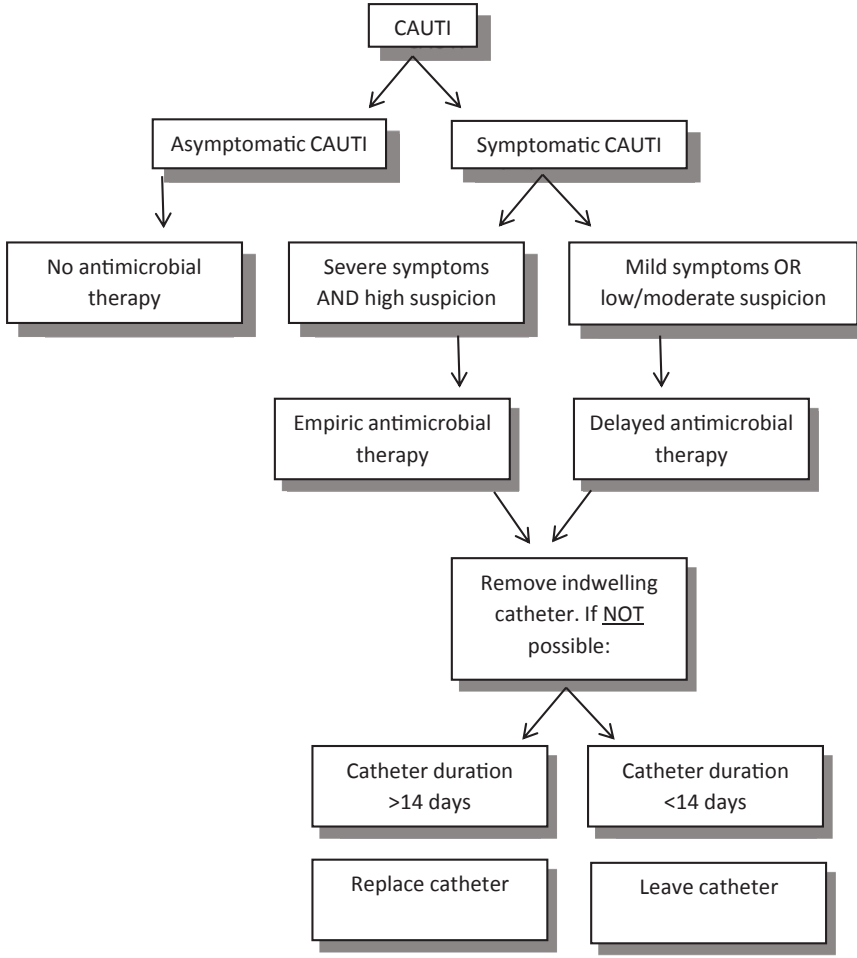

Fig. 3. Management of catheter-associated urinary tract infection (CAUTI).

trial found that a 5-day course of levofloxacin had equivalent therapeutic effect to a 10-day course in treating complicated UTI.[37] The 2009 Infectious Disease Society of America recommendations acknowledge the broad scope of evidence, noting that shorter courses may be appropriate in select patients with only mild lower urinary tract symptoms.[10] For patients with chronic indwelling catheters, longer durations of therapy up to 14 days may be required to prevent recurrence.[39]

If feasible, catheters should be removed before initiation of antimicrobial therapy for source control owing to the presence of biofilms. In patients with an ongoing need for urinary catheters, alternatives to indwelling catheters, as discussed subsequently, should be explored. In patients whom require continued indwelling catheterization, there exists only indirect evidence as to whether catheter replacement is warranted. In a prospective, randomized trial among elderly patients with chronic catheter needs, routine replacement of indwelling catheters before initiation of antimicrobial therapy was associated with a shorter time to fever defervescence, improved clinical status at 72 hours, and lower rate of recurrence in a 28-day follow-up.[31] Although this study was performed in a chronic catheter population, the dynamic of biofilms likely makes the bacterial burden of a long-term catheter similar to a short-term catheter within 3 to 10 days of catheterization.[26,27] Current Infectious Disease Society of America recommendations include replacing the urinary catheter if catheters have been in place for longer than 2 weeks (see **Fig. 3**).[10]

Epidural Analgesia and Urinary Catheters

In patients with postoperative thoracic or lumbar epidural analgesia, urinary catheters are commonly kept in place for the duration of epidural analgesia owing to concerns of urinary retention. However, emerging evidence challenges the need for continuous bladder drainage accompanying epidural analgesia.[40–42] In a prospective study among patients undergoing colorectal surgery with an epidural catheter, urinary catheter removal at 24 hours postoperatively was associated with increased urinary retention in only 12% of patients.[40] In a similar study among surgical patients with thoracic epidurals, patients who had urinary catheter removal on the morning after surgery had a longer return to post void residuals of less than 200 mL (345 vs 169 minutes); however, there were no adverse events or need for recatheterizations.[41] These data suggest that even in the subset of patients with urinary retention, retention is a transient phenomenon that resolves spontaneously without adverse events.

CATHER-ASSOCIATED URINARY TRACT INFECTION PREVENTION

Prevention summary

- Institutional guidelines for the use and maintenance of urinary catheters can reduce unnecessary catheterization, prolonged duration and incidence of CAUTI.
- Use of coated, impregnated, and/or silicone indwelling catheters have not demonstrated reproducible clinical benefits over standard noncoated latex catheters.
- Non-indwelling alternatives to urinary catheters should be considered daily and implemented as soon as feasible.
- Indications for catheter placement should be clearly reviewed before placement. Incontinence and caregiver convenience are not appropriate indications for urinary catheterization.

- Duration of catheterization is the strongest risk factor for catheterization.
- Catheter care should employ aseptic materials and techniques with vigilant maintenance of asepsis of the closed drainage system. Perineal washings may have a role in decreasing fecal contamination of the extraluminal catheter surface.
- Post removal, ultrasonographic bladder scanning can be a useful adjunct in the evaluation of retention. If retention is present, straight catheterization can be employed for up to 48 hours awaiting return of urinary bladder function.
- Systemic reminders and prompts for health care professionals regarding ongoing catheterization is an important element in increasing compliance with guidelines.

Effective prevention of CAUTI requires strict adherence to appropriate indications for placement of catheters, specified duration of catheterization, and proper catheter hygiene. The development of institutional protocols based on published guidelines for the use, maintenance, and removal of urinary catheters is an integral and proven method to reduce CAUTI.[6,7,10,43–45] In patients undergoing abdominal or orthopedic surgery, the institution of a multifaceted intervention to prevent CAUTI resulted in a 64% reduction in CAUTIs and 23% reduction in CAUTI-related antibiotic use, as reported by Stephan and colleagues.[46] Their intervention consisted of operating room guidelines restricting urinary catheter use to operations with anticipated duration of longer than 5 hours, or in older or higher risk patients with hip and knee replacements. In the postanesthesia care unit, voiding requirement and bladder measurement were removed as requisites for discharge, all catheters placed for long operations were removed, and all continuing catheterizations required explicit physician orders. Similarly, there were strict guidelines for removal of catheters on postoperative day 1 or 2 once on the surgical ward. Similar results have been reported in emergency room studies.[47] Prospective and retrospective studies have shown that up to one half of all short-term urinary catheters placed in acute care settings do not have appropriate indications, and that more than one third remained in place beyond the duration of the indication.[48–50] **Fig. 4** displays the authors' institutional guidelines for urinary catheter use.

Types of Urinary Catheters

A variety of alternatives to latex catheters have been investigated to target biofilms, reduce inflammation, and aid in the reduction of CAUTI. Alternatives include silicone-based catheters, or catheters that are silicone coated, antimicrobial impregnated, silver coated, or hydrogel coated. Antimicrobial-impregnated and silver-coated catheters were developed to retard biofilm formation and impede bacterial proliferation.[10,51] The use of silicone was thought to decrease urethral inflammation and consequently UTI development, and the hydrogel surface is theorized to prevent biofilm formation by changing surface affinity for biofilms.[10,52] The efficacy of these alternative catheters over latex catheters have been widely investigated but have yet to yield consistent reductions in CAUTI rates.[5,10] In the UK, a multicenter randomized trial was conducted comparing the efficacy and cost effectiveness of silicone catheters impregnated with nitrofurazone and silver alloy-coated latex catheters compared with standard polytetrafluoroethylene-coated latex catheters in mostly surgical patients requiring shorter term catheterizations. The analysis revealed no improvement in symptomatic CAUTI development in patients with the antimicrobial-impregnated catheter or the silver alloy-coated catheter.[51]

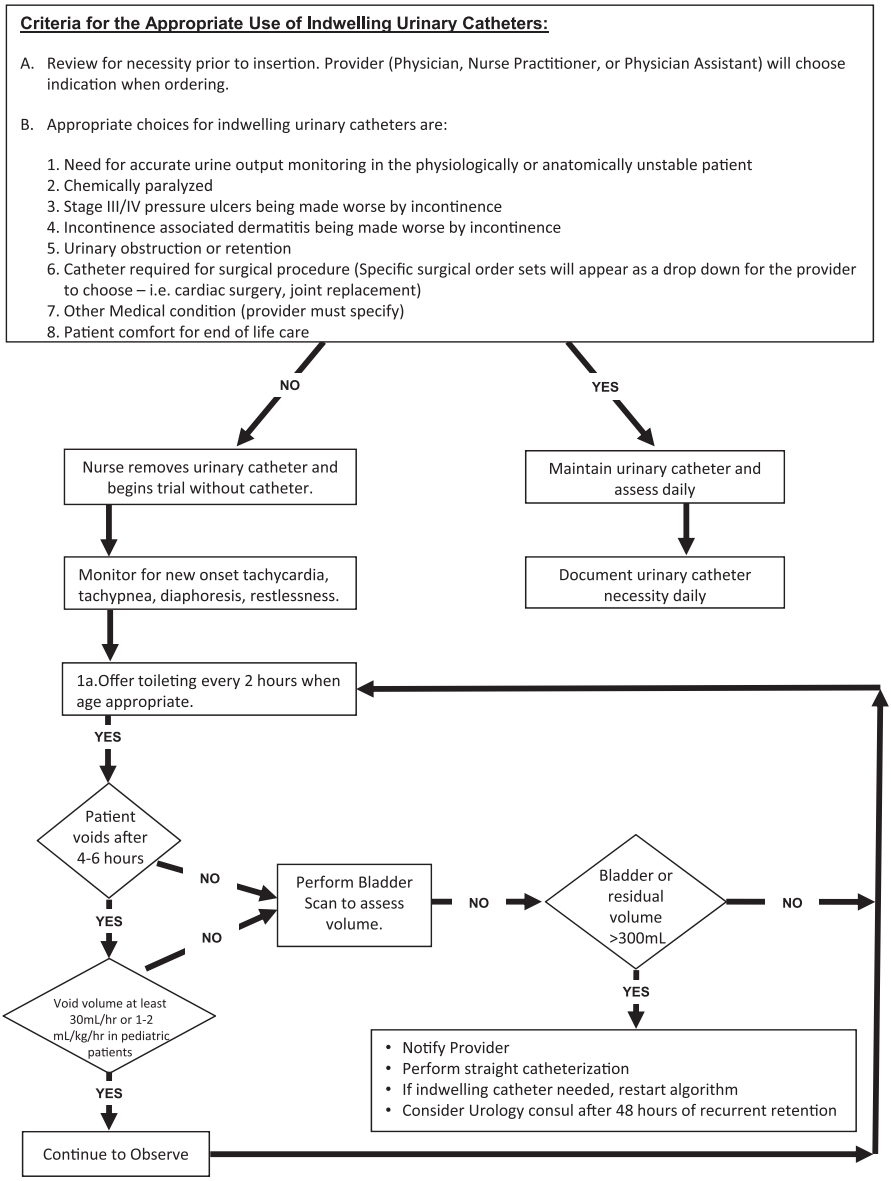

Fig. 4. Virginia Commonwealth University Health System (VCUHS) guidelines for appropriate indwelling urinary catheter use and monitoring. (*Courtesy of* Virginia Commonwealth University Health System, Richmond, VA.)

Alternatives to Indwelling Urinary Catheterization

Alternatives to indwelling urinary catheters include intermittent catheterization and use of external collection devices like diapers, pads, and condom catheters for men. There are limited studies investigating the safety and efficacy of urethral straight catheterization in patients with short-term needs. In a meta-analysis of patients with short-term non–perioperative need for bladder drainage, suprapubic intermittent catheterization

was associated with a lesser risk of bacteriuria than indwelling catheters.[53] Extrapolating from such studies, and based on studies investigating the pathophysiology of bacteriuria development, it is reasonable to estimate that although straight catheterization includes similar risks of bacterial inoculation as indwelling catheter placement, the temporary nature of the straight catheter avoids the duration-related complications of biofilm ascension.[6,17]

In men, an alternative for those with incontinence is the condom catheter. Condom catheters are an external urine collection device that is associated with improved outcomes in a randomized trial by Saint and colleagues.[54] Men hospitalized at a Veteran's Affairs medical center aged 40 years and older were randomized to condom catheter or indwelling catheter, and those with condom catheters had decreased incidence of bacteriuria, symptomatic CAUTI, and death, and had improved patient comfort.[54] In women and men, the use of absorbent external collection devices in conjunction with behavioral interventions like hourly or 2 hourly mandatory toileting can reduce rates of CAUTI and associated patient morbidity.

Indwelling Urinary Catheter Indications

Before the insertion of a urinary catheter, thought should be given to its necessity as well as proposed duration. Appropriate indications include the need for urinary output monitoring in a critically ill patient with fluid status concerns, chemically paralyzed patients, incontinence-related wound concerns, genitourinary surgery, and acute urinary obstruction. Inappropriate uses include patient or nursing inconvenience owing to incontinence, need for urine samples, continued use beyond the perioperative period, or with prolonged epidural use (see **Fig. 4**). In patients with incontinence, alternatives to indwelling catheters should be explored.

Indwelling Urinary Catheter Duration

Duration of catheterization is the strongest risk factor for CAUTI, and therefore the continued need for indwelling urinary catheterization should be assessed daily.[17–20,48,55] In 1978, Garibaldi and associates[18] detailed an 8.1% increased risk of bacteriuria acquisition with each catheter day, adding that the risk in the first 24 hours of 7.4% was similar to the overall daily risk. This further emphasizes the notion that even temporary or very short-term catheterization (<24 hours) carries a continued and equal risk of bacteriuria development. In a more recent analysis of large prospective studies, urinary catheterization for longer than 6 days carried a relative risk of 5.1 to 6.8 of CAUTI development (**Table 1**).[56] In critically ill patients and patients with need for urinary output monitoring, the continued need for urinary catheter and exploration of other alternatives should be reexamined daily. Catheters placed for prolonged duration of surgery should be removed in the postanesthesia recovery unit if feasible, or within the first postoperative day. Similarly catheters should be removed upon cessation of chemical paralysis.

Catheter Care

Catheter care influences the development of bacteriuria and CAUTI. Aseptic materials and technique should be employed during insertion, including gloves, drapes, and periurethal cleaning. Closed drainage systems should be used ensuring that the collection system remains below the level of the bladder and there is no kinking of the tubing. Intraluminal contamination accounts 34% of CAUTI, and intraluminal contamination is almost exclusively owing to breaches in aseptic handing of the urinary collection system.[56]

Table 1
Risk factors for CAUTI

Factor	Relative Risk
Prolonged catheterization >6 d	5.1–6.8
Female gender	2.5–3.7
Catheter insertion outside operating room	2.0–5.3
Urology service	2.0–4.0
Other active sites of infection	2.3–2.4
Diabetes	2.2–2.3
Malnutrition	2.4
Azotemia (creatinine >2.0 mg/dL)	2.1–2.6
Ureteral stent	2.5
Monitoring of urine output	2.0
Drainage tube below level of bladder and above collection bag	1.9
Antimicrobial drug therapy	0.1–0.4

Abbreviation: CAUTI, catheter-associated urinary tract infection.
From Maki DG, Tambyah PA. Engineering out the risk for infection with urinary catheters. Emerg Infect Dis 2001;7(2):342–7.

Perineal washing may also have an impact on CAUTI development. A microbiologic analysis of CAUTI identified a high proportion of gastrointestinal origin bacteria, indicating likely fecal contamination across the perineum.[21] Similarly, genetic studies have suggested similarities between rectal *E. coli* flora and *E. coli* isolated from concurrent UTI.[57] One of the few studies to date investigating the role of perineal washing in UTI prevention in 1985 found no improvement in UTI development with hexachlorophene wipes; however, that study was conducted in women with recurrent UTI and without indwelling catheters.[58] The authors' institution has instituted daily perineal washing with chlorhexidine among patients in intensive care to minimize fecal contamination of the extraluminal surface of the indwelling catheter.

Post-Removal Monitoring

Catheters should be evaluated for the possibility of removal daily, with consideration given to alternatives to continued indwelling catheter use. Upon removal, the authors advocate offering toileting every 2 hours to patients and recording urine output. If patients have not urinated within 4 to 6 hours, or if they have urinated less than 30 mL/h after catheter removal, ultrasonographic bladder scanning should be employed to assess post void residuals or retained urine in the bladder (see **Fig. 4**).[59] In cases of bladder urine volumes of greater than 300 mL, straight catheterization should be employed for up to 48 hours before urologic consultation or replacement of indwelling catheter.[10] If patients have not voided within 6 hours and the bladder scan identifies less than 300 mL, the volume status of the patient should be evaluated.

Prevention Strategies

Strategies to decrease inappropriate use and duration of indwelling catheters, and thereby reduce rates of CAUTI, include the development of institutional protocols for catheter use, care, removal, and alternatives. Lack of awareness among health care providers of their patients' urinary catheterization status contributes to inappropriate, prolonged use of urinary catheters. In a study of health care provider

awareness, prescribing providers were unaware of urinary catheters in 22% to 38% of their inpatients. Furthermore, use of a urinary catheter was appropriate significantly more often in patients for whom the prescribing providers were aware of urinary catheter use.[60] Systemic reminder mechanisms can have a large impact on reducing inappropriate catheter use and prolonged duration.[61] In a meta-analysis of reminder systems, duration of catheter use decreased by 37% and CAUTI rates decreased by 52% with the use reminder systems.[62] The meta-analysis included studies that used systems with only reminders, and systems with reminders associated with stop order prompts. The systems with associated stop order prompts included a spectrum of those that prompted physicians to place a discontinue order, those that autogenerated a discontinue order, and those with expiring catheter orders that required active renewal by a physician. A significant reduction in catheter duration was only noted in the systems with reminders associated with stop orders.[62] At the authors' institution, all catheter placements require a physician order with an indication, and urinary catheters placed perioperatively expire automatically at 48 hours postoperatively, requiring active physician justification for continuation. Reminder systems encourage physicians and health care providers to critically assess the requirements of ongoing catheter use lest the presence of urinary catheters be lost in the myriad of decisions and factors to be considered.

SUMMARY

UTI, and particularly CAUTI, have a major impact on surgical patient outcomes, quality and safety reporting, and reimbursement. CAUTI are especially ominous owing to the sequelae of biofilms. Education regarding the diagnosis and definition of CAUTI can improve identification and encourage appropriate use of antimicrobial therapy. Institutional guidelines based on consensus statements can guide and standardize UTI therapy. Prevention of inappropriate use and duration of indwelling catheters is integral. Health care provider ordering and documentation of indication for catheter placement may prevent inappropriate use and limit duration. Additionally, systemic reminders associated with stop orders may encourage timely catheter removal, especially for perioperative indications. Daily systems reviewing urinary catheter use and alternatives to indwelling catheters may also serve to limit duration. Finally, prospective data collection on outcomes including urinary catheter use, duration, CAUTI, and bacteremia will enable quality and process improvement.

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