JAMA Surgery | Review

Foley Catheter Management
A Review

Anne P. Cameron, MD; Glenn T. Werneburg, MD, PhD

IMPORTANCE About 100 million urinary catheters are used globally each year. Urinary catheters are effective to establish bladder drainage, but they are associated with risks, including infection and encrustation. To mitigate the associated risks, an understanding of urinary catheter indications, placement and removal techniques, and maintenance is necessary.

OBSERVATIONS This review describes catheter management and complications. Specifically, catheter indications and alternatives, catheter types, insertion and removal techniques, and catheter maintenance are reviewed. Catheter-associated complications and strategies to minimize risk are described.

CONCLUSIONS AND RELEVANCE Using best practices related to catheter management optimizes bladder drainage while minimizing the associated risks, including catheter-associated urinary tract infection, catheter encrustations, bladder spasms, and catheter-associated pain.

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Author Affiliations: Department of Urology, University of Michigan, Ann Arbor.

Corresponding Author: Anne P. Cameron, MD, Department of Urology, University of Michigan, 1500 E Medical Center Dr, Ann Arbor, MI 48109 (annepell@med.umich.edu).

The urethral catheter was first described in the sixth century BC, by the Indian surgeon Sushruta in his text *Sushruta Samhita*.[1] Silver, iron, and wood were typical compositions at that time, with liquid butter used for lubrication. Soon after Goodyear developed the vulcanization technique by which rubber could be intentionally shaped, August Nélaton, MD (1807-1873), was credited with the invention of the Nélaton catheter, the first rubber catheter.[2] Initially, catheters were secured to the penis or sewn to the female urethra. In 1929, Frederic Foley, MD, first described a self-retaining "hemostatic bag catheter."[3] The design was refined and published in the *Journal of Urology* in 1937.[4] It was marketed as the Foley catheter by the C.R. Bard Company from 1935 onwards. Its name and general design remain in use today.

About 100 million urinary catheters are used globally every year, and about 20% of patients in US hospitals have a catheter at any given time.[5] Given the prevalence of catheter use globally, understanding optimal management of the urethral catheter is critical. First, the indications for catheterization, catheter choices, and the framework for choosing an effective catheter are discussed. Then, the techniques for insertion, maintenance, and removal are reviewed. Finally, the complications of catheterization and measures for prevention are described.

Indications

Appropriate indications for catheterization,[6,7] depending on the clinical context, include the following: acute urinary retention or bladder outlet obstruction, neurogenic lower urinary tract dysfunction, need for accurate urine output measurements (eg, in the context of critical illness or targeted diuresis), to assist in wound healing (eg, open wounds in genitourinary, sacral, or perineal regions) in patients after select surgical procedures (eg, urological surgery, prolonged surgery, surgery wherein accurate urine output measurement is necessary), and in cases wherein prolonged critical immobilization is expected (eg, potentially unstable spine or pelvic fractures, intensive care), and to provide comfort in the context of end-of-life care.

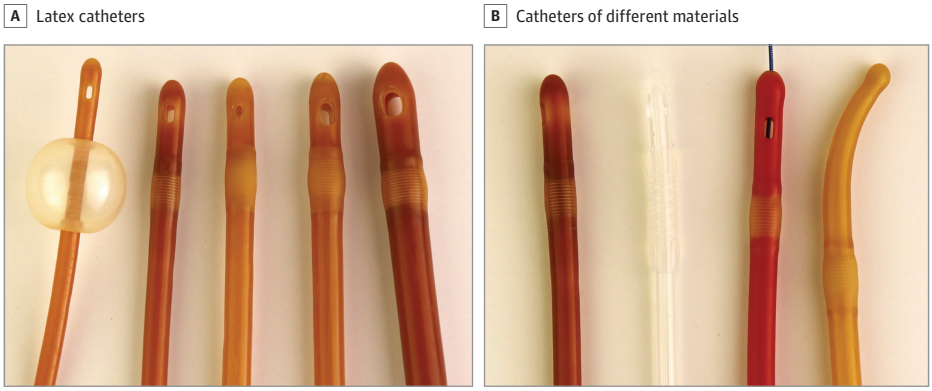
Inappropriate uses include catheterization as a substitute for nursing care for an individual with urinary incontinence, for convenience when toileting is cumbersome, as a means for obtaining urine specimens from an individual who can voluntarily provide a clean-catch urine specimen, or for prolonged postoperative duration in the absence of a specific indication.[6] Typically, it is recommended that a catheter be removed as soon as it is no longer needed after surgery, unless there is a specific indication for continuation.

Catheter Choices: Size, Shape, Material

The "French" catheter size system is the most commonly used today. The scale is as follows: the French metric is equal to 3 times the entire diameter of the catheter (not just the internal drainage channel). Thus, an 18F catheter corresponds to a catheter with a diameter of 6 mm (**Figure 1**A).

The second consideration is the geometry of the catheter tip. Most catheter tips are straight, but a coudé or "elbow" tip is also available. In most young male patients, a straight-tipped catheter is sufficient with 16F or 18F generally an appropriate choice (Figure 1A). In a male patient with a known or suspected enlarged prostate (older

Figure 1. Catheter Sizes, Geometry, and Material Types



A, Latex catheters of varying sizes. The leftmost catheter is shown with the balloon inflated with 10 mL. From left to right, catheters are 12F, 14F, 16F, 18F, and 24F. B, The leftmost catheter is a latex catheter with a straight tip, the left-mid catheter is a silicone catheter with a straight tip, the right-mid catheter is a hydrophilic red rubber catheter with a council tip, and the rightmost catheter is a latex catheter with a coudé tip. The council tip catheter is shown with a guidewire to demonstrate its council tip lumen and its ability to be advanced over the wire.

than 50 years), it is advisable to use a coudé tip catheter. The curve of the coudé should always be angled anteriorly, and a larger-bore catheter (18F rather than smaller) will pass more smoothly over an enlarged prostate since the slight increase in stiffness can pass through the prostatic urethra more easily. In a female patient, a 14F or 16F straight catheter is generally appropriate (Figure 1A).

The material type of the catheter should also be considered (Figure 1B). Clearly, latex catheters should not be used in patients with latex allergies or in those with spina bifida (in whom latex precautions are generally indicated). Silicone catheters are stiffer and could cause more urethral irritation. Many patients managed with long-term indwelling catheters prefer latex catheters, citing comfort. Many coatings and materials are in the development process, but those details are beyond the scope of this review.[8] The specific material type (silver alloy impregnated, nitrofurazone, coated latex, or silicone) is not associated with any real change in the rate of urinary tract infection (UTI).[9]

Catheters may have variable balloon sizes, but the typical balloon size is 10 mL. The balloon should be filled with the fluid volume recommended by the manufacturer of the catheter being used (located on the inflation port), thus avoiding an underfilled balloon that will assume an ellipsoid shape and be subject to inadvertent (and perhaps traumatic) removal. Smaller balloons (5 mL) exist on pediatric catheters given the smaller bladder size and larger balloons (30 mL) on hematuria catheters used after prostate surgery for traction. This maneuver should only be done with urological supervision. Sterile water or saline is typically used to fill the Foley balloon, given the theoretical possibility that other fluids might lead to crystallization and possible balloon rupture.[10]

Insertion and Removal

Insertion Technique

Indwelling catheter placement should be performed using a sterile technique. Supine positioning of the patient, with their head relaxed on a pillow, often will help alleviate any anxiety and relax pelvic floor muscles. Female patients may be placed with their legs in a butterfly position. After sterile preparation of the meatus, typically with povidone-iodine (Betadine), it is helpful to put lubricating anesthetic jelly (often 2% lidocaine) in the meatus via a prefilled syringe. If viscous lidocaine is not available, then the catheter tip should still be liberally lubricated. In male patients, traction on the penis by holding the penile glans and shaft with a nondominant hand (while avoiding occlusion of the urethra, which is in the ventral position on the shaft) will reduce angulation in the urethra and allows the catheter to pass much more easily. The dominant hand advances the catheter. In female patients, the urethral meatus is typically at the opening of the vagina and anatomically is the first structure below the clitoris.

Some resistance may be encountered near the area of the external sphincter (particularly in males with more sphincter resistance), which should be traversed with gentle pressure. Reassurance should be provided, and breath control exercises such as "blowing out candles" may be encouraged as the sphincter is traversed using a steady gentle pressure. The catheter should be advanced all the way to the hub in male patients and a minimum of halfway down the length of the catheter in female patients. Only after urine return is visualized and the catheter pushed a few more inches in the bladder should the balloon be inflated. After balloon inflation, which occurs in the center of the bladder, the catheter should be gently brought back to the bladder neck to the hub, which confirms correct placement of the catheter (**Figure 2**A and B). A catheter securement device should be used to secure the catheter to the leg, with slack on the tubing to allow leg movement (**Figure 3**).

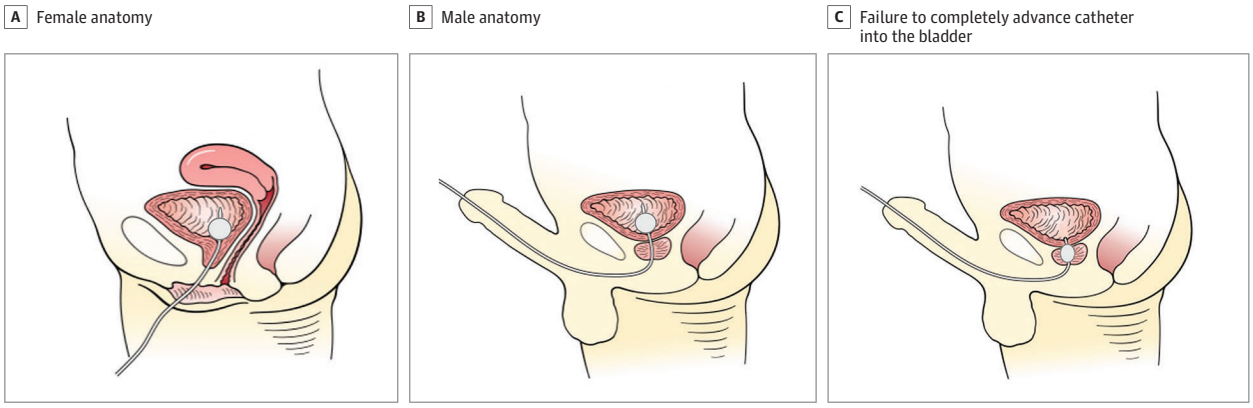
Removal Technique

For catheter removal, the balloon must be deflated completely using a syringe. Because the balloon could be filled with any amount of fluid (even if it is designed to hold a certain amount), it is critical to empty fluid from the balloon port until it is empty. Avoid kinking of the catheter tubing since a kinked (occluded) port tube is a common reason for an incompletely emptied catheter balloon. Next, the catheter should be gently removed from the urethra in a smooth motion. Troubleshooting a nondeflating balloon beyond strong syringe suction of the port is beyond the scope of this review and should prompt urological referral as it will often involve needle puncture transcutaneously.[11,12]

Special Considerations and Pitfalls

One pitfall in catheter insertion is inflation of the balloon in the urethra rather than the bladder (Figure 2C), which is avoided by advancing the catheter to the hub and confirming the catheter is indeed in the bladder. This confirmation requires either visualizing

Figure 2. Illustration of Correct and Incorrect Catheter Placement



Correct urinary catheter placements are shown in female (A) and male (B) anatomy. The balloon is inflated once the catheter is positioned within the bladder and placement is confirmed by visualization of urine return or successful fluid irrigation and aspiration. Failure to completely advance and confirm the catheter placement in the bladder may result in balloon inflation within the prostatic urethra (C), which could cause trauma, discomfort, and catheter dysfunction.

urine draining in the tube or, if the bladder is not full, irrigating and aspirating with a catheter tip syringe. The catheter will not irrigate in if it is folded or bent in the prostate, and it will not aspirate out if the tip is not in the bladder.

In a patient with known stricture disease, using a smaller catheter can make catheter placement easier, and a consultation with the urologic service is prudent. A more common cause of difficult Foley catheter placement is a traumatic catheter placement, where excessive pressure is placed on the Foley catheter while it is being inserted in a male patient at the external sphincter. In these instances, the catheter perforates the urethra and causes a "false passage" (usually posteriorly, at the 6-o'clock and/or surrounding positions) at the level of the external sphincter. This will then result in subsequent catheter passes exacerbating the false passage and significant urethral bleeding. If significant urethral bleeding is encountered during Foley catheter placement, the Foley should be removed and a urology consult placed since it will likely require cystoscopically guided council tip catheter placement over a guidewire (catheter with a reinforced hole at the tip for wire guidance) (Figure 1B). Any patient with a traumatic catheterization should receive antibiotics, given their elevated risk for infection in the context of breached urinary mucosa.

Another potential difficulty is locating the female meatus in cases where it may be deeper in the vagina, which occurs more often in older patients and patients with obesity. Placement of a catheter in such cases with the female patient in a hospital bed or supine is extremely difficult. Repositioning to the lithotomy position changes the angle of the meatus, improving its visibility. A speculum may be used to visualize the anterior vaginal wall. A coudé catheter can also be helpful in directing the tip of the catheter anteriorly to follow the expected course of the urethra.

Management of the Catheter

Patients with indwelling Foley catheters should be given instructions on genitourinary and perineal care using soap and water to keep the insertion site clean but not any astringent or alcohol-based products that would be irritating to the genitalia. Patients should be instructed to keep their collection bag dependent (below the level of the urinary bladder) and can switch from a leg bag to a night bag by using an alcohol swab on the reusable bag before connection. The system should remain closed and always connected to a drainage bag. The drainage bag should be emptied when it is about halfway full, thus ensuring that an overfull bag does not provide bag pressure, preventing drainage. Although there are no clear recommendations on catheter change frequency, most patients undergo catheter exchanges approximately every 4 weeks.

Complications

The cornerstone for avoiding catheter-associated complications is to identify and implement alternatives to catheterization. Urinary catheters should only be used when needed and removed as soon as they are no longer necessary. Indwelling catheters have several potential risks, including UTI, encrustation, discomfort and irritation of the tube to the urethra and bladder, catheter erosion of the urethra, and urine leakage around the catheter (**Table**).

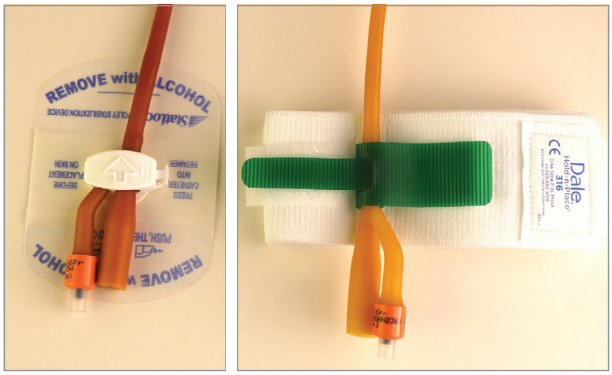
Catheter-Associated Urinary Tract Infection

Immediately after catheter insertion, the risk of bacteriuria is reported at 3% to 7% per day, resulting in a 98% risk of bacterial colonization of the bladder at 30 days.[13] Catheter-associated UTIs (CAUTIs) are a serious health problem; in hospitalized patients, they lead to increased length of stay, higher cost, and excess antibiotic use with the risk of antimicrobial resistance and higher mortality.[14] Patients at increased risk for CAUTI are older, are female and have diabetes and longer duration of the catheter. These health care–associated infections are reported to the National Healthcare Safety Network. It is estimated that 50% to 70% could be prevented,[14] and most hospitals have measures in place to reduce this incidence.

Bacteria typically colonize the bladder via an ascending route: from the perineum up the urethra. Because the patient is not voiding,

Figure 3. Catheter Securement Devices

A Adhesive securement B Wrap-around securement



After urinary catheter placement, the catheter should be secured in place to avoid inadvertent removal or disconnection of the closed system and to minimize tension on the urethra. Common securement devices may adhere to (A) or wrap around (B) the leg. The securement devices should generally be placed about 1 inch proximal to a position wherein a catheter tubing would be taught, maintaining a gentle curve of the catheter. This position ensures there is no undue tension on the urethral or bladder neck.

Table. Complications of Urinary Catheters and Mechanisms for Prevention

Complication	Prevention approach
Catheter-associated urinary tract infection	Seek alternatives to catheterization. Use a sterile insertion technique and perineal care. Consider gentamicin irrigation in individuals with recurrent urinary tract infection. Maintain a closed drainage system. Maintain continuous drainage. Remove as soon as it is no longer indicated.
Encrustation	Exchange catheters at shorter intervals than typical clogging time. Consider a larger catheter size. Teach self-irrigation.
Bladder spasms	Avoid kinked tubing. Ensure a steady flow and keep the drainage bag below the level of the bladder. Consider initiation of an anticholinergic or β-3 agonist agent or intravesical botulinum toxin injection.
Catheter-associated discomfort/pain	Secure the catheter. Consider a hydrogel-coated catheter. Identify and treat any infections. Consider a course of phenazopyridine hydrochloride if there are no contraindications.
Urethral erosion and traumatic hypospadias	Avoid long-term urethral catheter use. Avoid upsizing catheters or increasing the fluid volume in the balloon. Secure the catheter without tension. Consider alternatives to urethral catheters, including a suprapubic tube.

the urethra's best defense against ascending infection, the antegrade urine flow, is absent, and bacteria become adherent to the urethral catheter. Bacterial biofilm formation ensues on the catheter and its balloon and/or eyelets.[15] This makes eradication of the bacteria nearly impossible while the catheter remains in place. Changing the catheter has little to no impact on bacteriuria because the bacteria are present in the bladder and on the catheter and will quickly reform the biofilm. Steps that reduce the rate of UTI include proper handwashing before manipulating the catheter or drainage bag, cleansing the catheter and urethral meatus with soap and water, maintaining a closed drainage system, using smaller catheters such as 14F or 16F in the urethra (reduces urethral trauma), and avoiding unnecessary breaks in the drainage system for irrigation or sample collection.[16] Again, the best prevention of CAUTI is avoiding the use of indwelling catheters and removing those in place as soon as it is safe.[17]

Symptoms of a UTI include bladder pain, suprapubic pain, spasms, flank pain, and fever.[18] Depending on the clinical context, these symptoms generally require prompt treatment with culture-specific antibiotics. If a specimen is needed from a patient with an indwelling catheter, it is recommended to perform catheter replacement before obtaining the specimen if the catheter has been in place for 7 or more days. This will avoid culturing of catheter biofilm-associated bacteria rather than the organisms present in the bladder urine. Catheters should also be changed during the treatment for infection and in the context of encrustation. Asymptomatic bacteriuria, or bacterial colonization of the urine in the absence of symptoms, is extremely common and does not generally require screening or treatment because it is not pathological.[18,19]

Clogging, Encrustation, and Bladder Stones

Fifty percent of long-term catheter users eventually develop encrustation,[20] a phenomenon caused by bacterial colonization and biofilm formation (usually *Proteus mirabilis*), leading to hydrolyzation of urea, increased urinary pH, and crystallization and deposition of magnesium and calcium phosphates.[20] The encrustation continues to develop until a catheter becomes clogged, necessitating more frequent changes. Bladder irrigation to reduce blockage using Renacidin (citric acid, glucono delta lactone, and magnesium carbonate), acetic acid, and most other tested solutions have not shown benefit.[21] New data have emerged on the utility of aminoglycoside bladder instillations for reducing UTI.[22] Hydration is helpful, especially with fluid and citrated drinks that will increase urinary pH.[20]

For patients with recurrent episodes of catheter clogging or encrustation, home irrigation with a catheter tip syringe and normal saline or water may be effective for reducing urgent care and emergency department visits for catheter clogs. Irrigation using high volumes of 100 to 200 mL either daily or as needed for clogging and teaching patients and caregivers to perform exchanges themselves may be effective. More frequent catheter changes are often effective, as each exchange resets the encrustation.

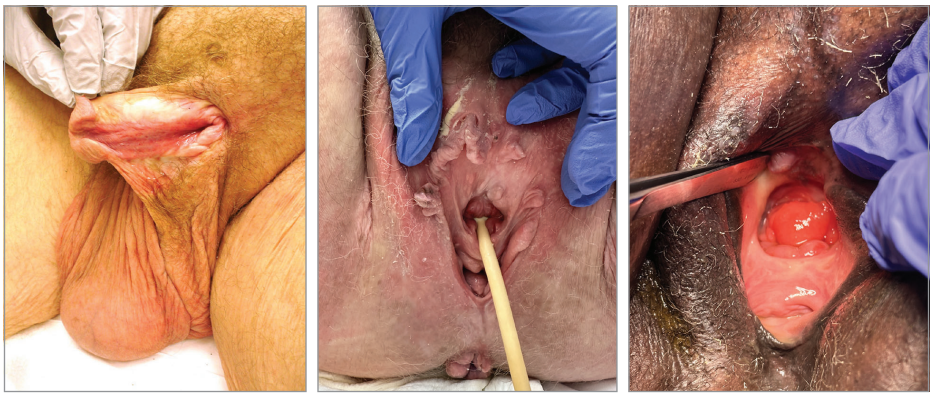
Encrustations may dislodge and act as a nidus for bladder stones. Patients with long term catheters are at a 9-fold risk of bladder stones.[23] Additionally, extremely long term (≥10 years) bladder epithelial irritation from bacteriuria and or catheter irritation puts these patients at risk for bladder cancer.[24] The risk increase is minimal with catheters in place for less than 10 years, but after this time, the risk increases substantially. Cystoscopic screening and urine cytology screening have been reported[25] but unfortunately do not improve detection. Patients with catheters who develop gross hematuria all require assessment with cystoscopy because hematuria is a hallmark sign of bladder cancer.[26]

Bladder Spasms and Catheter-Associated Discomfort

Bladder spasms and urgency are common conditions with both long- and short-term catheters. Leakage around a catheter (bypass leaking) can occur when tubing is kinked, the catheter is clogged, or the

Figure 4. Complications From Prolonged Indwelling Catheterization

A Urethral erosion in a male patient B Urethral erosion in a female patient C Urethral erosion in a female patient



In the male patient (A), urethral erosion may ensure leading to a penile defect. This defect can progress over time and may ultimately involve the entire penile shaft. In the female patient (B and C), the urethral erosion may be more subtle, but ultimately it may lead to incontinence per urethra even despite suprapubic catheterization.

drainage bag is stored above the level of the bladder.[16] If bypass leaking persists after correcting these issues, patients can be treated with the same oral agents used for overactive bladder, including anticholinergics and β-3 agonists.[27] However, anticholinergics can sometimes impair a trial of void[14] and are associated with constipation, dry mouth, dry eyes, and the risk of delirium.[28] Long-term catheter bypass leaking occurs in 43% of patients[29]; treatment with anticholinergics or β-3 agonists will assist with leaking and improve bladder compliance and reduce the risk of upper tract deterioration over time.[30,31]

Many patients with urethral catheters have perineal/vaginal or penile discomfort with the catheter in place. Hydrogel-coated latex catheters are softer than silicone and have a less rigid balloon when deflated compared with silicone and may be preferred for the ease and comfort associated with removal.[30] Catheter securement is of paramount importance, especially in patients with delirium or altered sensorium, who may be at risk for self-removal (Figure 3). Securement prevents irritation during ambulation and reduces the risk for inadvertent dislodgement, which may be traumatic if the balloon remains inflated.[16] Dysuria and burning from a catheter can be treated acutely with phenazopyridine hydrochloride, which will turn the urine orange and should be used with caution in those with renal dysfunction.

Urethral Erosion and Traumatic Hypospadias

In the long term, urethral catheters may cause urethral erosion in both female and male patients (**Figure 4**).[32] Those at risk for urethral erosion typically have a catheter in place for months to years. Other risks for erosion include lack of catheter securement, reduced or absence perineal sensation (eg, in the context of spinal cord injury), prolonged sitting, and/or altered cognition.[30] Also, larger-bore catheters increase pressure on the tissue, which results in more bladder neck and urethral erosion. Over time, men present with a hypospadiac-appearing meatus that can progress to an entire filet of the penis due to pressure erosion (Figure 4A). This is typically irreparable except in very specific circumstances, and the key to effective management is prevention. In female patients, the presentation is more subtle (Figure 4B and C). They often present with leakage around the catheter, and a common erroneous approach is to upsize the catheter, which results in further erosion until they expel the balloon inflated via the urethra, which often prompts filling the balloon with more fluid. Both maneuvers may exacerbate the problem, which is pressure necrosis of the urethra. Further, the larger balloon causes more bladder spasms, with no reduction in expulsion, and causes more trauma when it occurs.[30] Long-term leakage around a catheter is often the first sign of erosion and a signal that the urethral catheter needs to be removed or replaced with another mechanism for bladder drainage, such as a suprapubic tube. Any patient with a long-term indwelling catheter should have the meatus examined at longitudinal intervals.[32,33] An early transition to a suprapubic tube in those patients not expected to recover voiding function will often resolve the damage. A suprapubic tube is the best choice for most patients who will require long-term bladder drainage assistance, since the suprapubic route is generally more comfortable[32] and preferred by most patients, given it is not associated with urethral erosion. Further, the tube and balloon inhabit the bladder dome, a much less sensitive location in the bladder than the trigone, the commonly contacted area of a urethral catheter. Also, when using suprapubic tubes to reduce catheter clogging, tubes are often upsized to 20F or 22F without any risk of catheter discomfort, and the larger lumen can improve drainage compared with the recommended 14F or 16F urethral catheter.

Urethral erosion may lead to intractable incontinence and its sequelae, including decubitus ulcers and skin breakdown. In certain conditions, the incontinence can be halted with a pubovaginal sling and suprapubic tube placement[34] or a surgical urethral closure and suprapubic tube.[35] However, if the erosion has completely eroded the urethra to the pubic bone, the only solution is urinary diversion, for example, with an ileal conduit.

Team-Based Prevention and Alternatives to Catheterization

Long-term indwelling catheters are best managed by a catheter care team. Many models have proven effective and provide assistance to patients with catheters.[30] One of the cornerstones of CAUTI risk reduction is removal of the catheter as soon as it is no longer needed.[36,37] The timing of removal will depend on the

indication for Foley catheter placement. For example, in general an episode of acute retention can be treated with 3 to 14 days of bladder decompression with Foley catheter and then a trial of void. In male patients, tamsulosin, 0.4 mg, daily for at least 3 days can increase the chances of a successful trial of void and should be started at the time of Foley catheter insertion[38] unless there are contraindications. In patients with long-term retention, clean intermittent catheterization is the gold standard bladder drainage management.[33]

Management of incontinence in hospitalized men can be performed with a condom catheter, a body-worn urinal attached to the penis collecting urine without instrumenting the urinary tract. Newer strategies are increasingly being used for continence management of patients who are bedbound. For example, PureWick catheters, available for both men and women, use wall suction to wick away urine.[39,40] These can be obtained for home or inpatient use. UTIs that occur while using these devices are not considered CAUTIs because there is no indwelling catheter present, and these devices have been commonly adopted in hospitals. Individuals who are being managed with an indwelling catheter solely for urinary incontinence should be referred to the urologic service, given that their incontinence may be more optimally managed with another modality or intervention. In individuals with a long-term need for bladder drainage assistance, a suprapubic tube or intermittent catheterization is preferable to an indwelling catheter when duration is longer than 5 days.[41]

Conclusions

Indwelling catheters are an important tool in the management of retention both in the short-term and long-term care of patients. To avoid urethral injury, proper insertion technique should be used. Patient comfort can be maximized with careful catheter care. Complications such as infection, bladder and urethral discomfort, encrustation, and urethral erosion can be minimized by only using a catheter for the minimum amount of time needed; even better is to avoid catheter placement when there are less invasive options. The statement and issue published by the American Urological Association title "Indwelling Urinary Catheter Management of the Acute Patient"[14] is available online; it includes many toolkits and resources for clinicians.

ARTICLE INFORMATION

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REFERENCES

1. Bloom DA, McGuire EJ, Lapides J. A brief history of urethral catheterization. *J Urol*. 1994;151(2):317-325. doi:10.1016/S0022-5347(17)34937-6

2. Mattelaer JJ, Billiet I. Catheters and sounds: the history of bladder catheterisation. *Paraplegia*. 1995;33(8):429-433.

3. Foley FE. Cystoscopic prostatectomy a new procedure and instrument; preliminary report. *J Urol*. 1929;21(3):289-306. doi:10.1016/S0022-5347(17)73103-5

4. Foley FE. A self-retaining bag catheter: for use as an indwelling catheter for constant drainage of the bladder. *J Urol*. 1937;38(1):140-144. doi:10.1016/S0022-5347(17)71936-2

5. Nicastri E, Leone S; International Society for Infectious Diseases. Guide to infection control in the healthcare setting: hospital associated urinary tract infections. 2021. Accessed March 5, 2025. https://isid.org/wp-content/uploads/2019/07/ISID_GUIDE_HOSPITAL_ACQUIRED_UTI.pdf

6. Gould CV, Umscheid CA, Agarwal RK, Kuntz G, Pegues DA; Healthcare Infection Control Practices Advisory Committee. Guideline for prevention of catheter-associated urinary tract infections 2009. *Infect Control Hosp Epidemiol*. 2010;31(4):319-326. doi:10.1086/651091

7. 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-S34. doi:10.7326/M14-1304

8. Werneburg GT. Catheter-associated urinary tract infections: current challenges and future prospects. *Res Rep Urol*. 2022;14:109-133. doi:10.2147/RRU.S273663

9. Lam TB, Omar MI, Fisher E, Gillies K, MacLennan S. Types of indwelling urethral catheters for short-term catheterisation in hospitalised adults. *Cochrane Database Syst Rev*. 2014;(9):CD004013. doi:10.1002/14651858.CD004013.pub4

10. Huang JG, Ooi J, Lawrentschuk N, Chan ST, Travis D, Wong LM. Urinary catheter balloons should only be filled with water: testing the myth. *BJU Int*. 2009;104(11):1693-1695. doi:10.1111/j.1464-410X.2009.08672.x

11. Shapiro AJ, Soderdahl DW, Stack RS, North JH Jr. Managing the nondeflating urethral catheter. *J Am Board Fam Pract*. 2000;13(2):116-119. doi:10.3122/15572625-13-2-116

12. Davies BW, Thomas DG. Management of non-deflating Foley catheters in women: a new technique. *Br J Urol*. 1994;74(1):117. doi:10.1111/j.1464-410X.1994.tb16558.x

13. Garibaldi RA, Burke JP, Britt MR, Miller MA, Smith CB. Meatal colonization and catheter-associated bacteriuria. *N Engl J Med*. 1980;303(6):316-318. doi:10.1056/NEJM198008073030605

14. Averch TD, Griebling T, Newman D, Peterson A, Stoffel J; American Urological Association. Indwelling urinary catheter management of the acute patient. Accessed March 5, 2025. https://www.auanet.org/guidelines-and-quality/quality-and-measurement/quality-improvement/clinical-consensus-statement-and-quality-improvement-issue-brief-(ccs-and-qiib)/indwelling-urinary-catheter-management-of-the-acute-patient

15. Werneburg GT, Nguyen A, Henderson NS, et al. The natural history and composition of urinary catheter biofilms: early uropathogen colonization with intraluminal and distal predominance. *J Urol*. 2020;203(2):357-364. doi:10.1097/JU.0000000000000492

16. Cochran S. Care of the indwelling urinary catheter: is it evidence based? *J Wound Ostomy Continence Nurs*. 2007;34(3):282-288. doi:10.1097/01.WON.0000270823.37436.38

17. 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):1209-1231. doi:10.1017/ice.2023.137

18. Werneburg GT, Rhoads DD. Diagnostic stewardship for urinary tract infection: a snapshot of the expert guidance. *Cleve Clin J Med*. 2022;89(10):581-587. doi:10.3949/ccjm.89a.22008

19. Nicolle LE, Gupta K, Bradley SF, et al. Clinical practice guideline for the management of asymptomatic bacteriuria: 2019 update by the Infectious Diseases Society of America. *Clin Infect Dis*. 2019;68(10):e83-e110. doi:10.1093/cid/ciy1121

20. Stickler DJ, Feneley RC. The encrustation and blockage of long-term indwelling bladder catheters: a way forward in prevention and control. *Spinal Cord*. 2010;48(11):784-790. doi:10.1038/sc.2010.32

21. Shepherd AJ, Mackay WG, Hagen S. Washout policies in long-term indwelling urinary catheterisation in adults. *Cochrane Database Syst Rev*. 2017;3(3):CD004012. doi:10.1002/14651858.CD004012.pub5

22. Cameron AP, Castrodad PM, Troost J, Forchheimer M, Tate DG. Effectiveness and patient perspective on the use of intravesical gentamicin instillations to treat recurrent urinary tract infections in neurogenic lower urinary tract dysfunction. *Neurourol Urodyn*. 2024;43(8):1916-1923. doi:10.1002/nau.25513

23. Chen Y, DeVivo MJ, Lloyd LK. Bladder stone incidence in persons with spinal cord injury: determinants and trends, 1973-1996. *Urology*. 2001;58(5):665-670. doi:10.1016/S0090-4295(01)01374-7

24. Groah SL, Weitzenkamp DA, Lammertse DP, Whiteneck GG, Lezotte DC, Hamman RF. Excess risk of bladder cancer in spinal cord injury: evidence for an association between indwelling catheter use and bladder cancer. *Arch Phys Med Rehabil*. 2002;83(3):346-351. doi:10.1053/apmr.2002.29653

25. Cameron AP, Lai J, Saigal CS, Clemens JQ; NIDDK Urological Diseases in America Project. Urological surveillance and medical complications after spinal cord injury in the United States. *Urology*. 2015;86(3):506-510. doi:10.1016/j.urology.2015.06.005

26. Holzbeierlein JM, Bixler BR, Buckley DI, et al. Diagnosis and treatment of non-muscle invasive bladder cancer: AUA/SUO guideline: 2024 amendment. *J Urol*. 2024;211(4):533-538. doi:10.1097/JU.0000000000003846

27. Cameron AP, Chung DE, Dielubanza EJ, et al. The AUA/SUFU guideline on the diagnosis and treatment of idiopathic overactive bladder. *J Urol*. 2024;212(1):11-20. doi:10.1097/JU.0000000000003985

28. Nishtala PS, Salahudeen MS, Hilmer SN. Anticholinergics: theoretical and clinical overview. *Expert Opin Drug Saf*. 2016;15(6):753-768. doi:10.1517/14740338.2016.1165664

29. Wilde MH, McDonald MV, Brasch J, et al. Long-term urinary catheter users self-care practices and problems. *J Clin Nurs*. 2013;22(3-4):356-367. doi:10.1111/jocn.12042

30. Reid S, Brocksom J, Hamid R, et al. British Association of Urological Surgeons (BAUS) and Nurses (BAUN) consensus document: management of the complications of long-term indwelling catheters. *BJU Int*. 2021;128(6):667-677. doi:10.1111/bju.15406

31. Werneburg GT, Stoffel JT. *Bladder Compliance: How We Define It and Why It Is Important*. Urologic Clinics; 2024. doi:10.1016/j.ucl.2023.12.001

32. English SF. Update on voiding dysfunction managed with suprapubic catheterization. *Transl Androl Urol*. 2017;6(suppl 2):S180-S185. doi:10.21037/tau.2017.04.16

33. Ginsberg DA, Boone TB, Cameron AP, et al. The AUA/SUFU guideline on adult neurogenic lower urinary tract dysfunction: diagnosis and evaluation. *J Urol*. 2021;206(5):1097-1105. doi:10.1097/JU.0000000000002235

34. Chancellor MB, Erhard MJ, Kiilholma PJ, Karasick S, Rivas DA. Functional urethral closure with pubovaginal sling for destroyed female urethra after long-term urethral catheterization. *Urology*. 1994;43(4):499-505. doi:10.1016/0090-4295(94)90241-0

35. Rovner ES, Goudelocke CM, Gilchrist A, Lebed B. Transvaginal bladder neck closure with posterior urethral flap for devastated urethra. *Urology*. 2011;78(1):208-212. doi:10.1016/j.urology.2010.11.054

36. Shadle HN, Sabol V, Smith A, Stafford H, Thompson JA, Bowers M. A bundle-based approach to prevent catheter-associated urinary tract infections in the intensive care unit. *Crit Care Nurse*. 2021;41(2):62-71. doi:10.4037/ccn2021934

37. Davies PE, Daley MJ, Hecht J, et al. Effectiveness of a bundled approach to reduce urinary catheters and infection rates in trauma patients. *Am J Infect Control*. 2018;46(7):758-763. doi:10.1016/j.ajic.2017.11.032

38. Lerner LB, McVary KT, Barry MJ, et al. Management of lower urinary tract symptoms attributed to benign prostatic hyperplasia: AUA guideline part I, initial work-up and medical management. *J Urol*. 2021;206(4):806-817. doi:10.1097/JU.0000000000002183

39. Khosla L, Sani JM, Chughtai B. Patient and caretaker satisfaction with the PureWick system. *Can J Urol*. 2022;29(4):11216-11223.

40. Bagley K, Severud L. Preventing catheter-associated urinary tract infections with incontinence management alternatives: PureWick and condom catheter. *Nurs Clin North Am*. 2021;56(3):413-425. doi:10.1016/j.cnur.2021.05.002

41. Han CS, Kim S, Radadia KD, et al. Comparison of urinary tract infection rates associated with transurethral catheterization, suprapubic tube and clean intermittent catheterization in the postoperative setting: a network meta-analysis. *J Urol*. 2017;198(6):1353-1358. doi:10.1016/j.juro.2017.07.069